DOCUMENT RESUME

ED 427 783 IR 057 288

AUTHOR	Ernst, Martin L.
TITLE	At the Heart of Evolving Literacy: A Framework for Action.
INSTITUTION	Harvard Univ., Cambridge, MA. Center for Information Policy Research.
ISBN	ISBN-1-879716-44-5
PUB DATE	1997-00-00
NOTE	122p.
PUB TYPE	Reports - Research (143)
EDRS PRICE	MF01/PC05 Plus Postage.
DESCRIPTORS	*Computer Literacy; *Information Literacy; Information Management; Information Skills; Information Technology; Internet; Strategic Planning; Technological Advancement; Users (Information)
IDENTIFIERS	*Computer Use; Computer Users; Digital Technology; Technology Role

ABSTRACT

This report is concerned with information, technology, education, and literacy and with the dynamics that interrelate them. The report reviews and clarifies how the dynamics operate, examines many of their consequences, and suggests some kinds of actions that may prove necessary for both individuals and organizations to survive successfully in the emerging information environment. The main themes of the report include the following: The range of uses of personal computers and related systems will continue to expand for at least several decades, and the importance of their roles in essentially all information activities will continue to increase. Both people and organizations will continue to encounter difficult new problems in managing information resources in the face of potential overloads of many kinds; both computer skills and knowledge of subject underlying many kinds of applications will be required. Instead of developing long-range plans based on detailed forecasts of the future information environment, short-range (2-4 years), incremental, action-oriented plans may be more appropriate if guided by a long-range vision. Possibilities exist for extensive and better use of computers as aids in efforts to lighten some of the major work overloads faced. Computer skills are well on the way to becoming a key component of literacy in the future. Seven figures and tables provide further information throughout the text. Includes a list of acronyms. (Author/AEF)

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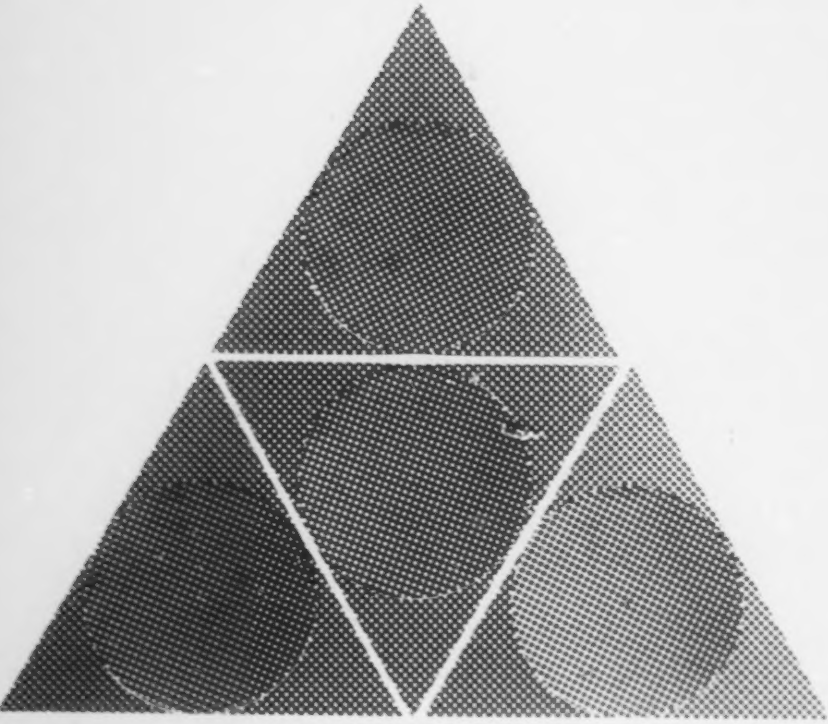
At the Heart of Evolving Literacy: A Framework for Action

Martin L. Ernst

Program on Information Resources Policy



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Martin L. Ernst

Program on Information Resources Policy

Harvard University
Center for Information Policy Research
Cambridge, Massachusetts

A publication of the Program on Information Resources Policy.

At the Heart of Evolving Literacy: A Framework for Action

Martin L. Ernst
December 1997, P-97-3

Project Director
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The Program on Information Resources Policy is jointly sponsored by Harvard University and the Center for Information Policy Research.

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65 Rear Mt. Auburn Street, Cambridge MA 02138. (617) 495-4114. E-mail: pirp@deas.harvard.edu
http://www.pirp.harvard.edu Printed in the United States of America. ISBN 1-879716-44-5

Printing 5 4 3 2 1

December 1997

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Acknowledgements

The author gratefully acknowledges the following people who reviewed and commented critically on an earlier version of this report, entitled *Thinker, Zapper, Couch Potato: Shaping the Nature of Future Literacy*. Without their consideration, input, and encouragement, this study could not have been completed: John A. Arcate, Herbert R. Brinberg, Y. S. Give'on, Joost Kist, Lloyd N. Morrisett, Vincent Mosco, William H. Read, Kenneth W. Rogers, and John Rothman.

These reviewers and the Program's affiliates, however, are not responsible for or necessarily in agreement with the views expressed here, nor should they be blamed for any errors of fact or interpretation.

Executive Summary

This report is concerned with information, technology, education, and literacy and with the dynamics that interrelate them. Rapid advances in digital electro-optic technologies have stimulated changes in these dynamics that are influencing almost all important personal, business, political, and social activities worldwide. The process of change is itself so rapid and volatile that the direction and general nature of potential change are uncertain. Given this situation, the first step—which is also a prerequisite for later effective planning and action—is to develop a thorough understanding of what is going on and why. This report reviews and clarifies how the dynamics operate, examines many of their consequences, and suggests some kinds of actions that may prove necessary for both individuals and organizations to survive successfully in the emerging information environment.

The main themes of the report include the following:

- The range of uses of personal computers and related systems (broadly defined) will continue to expand for at least several decades, and the importance of their roles in essentially all information activities will continue to increase. Although rapid growth in technical capabilities appears highly likely, the detailed directions in which this growth is applied, and even the broad features of future systems, are uncertain.

- Both people and organizations will continue to encounter difficult new problems in managing information resources in the face of potential overloads of many kinds. Individuals in particular will be expected to understand and to be able to perform many more "kinds of things" than at present. Meeting this need will require both computer skills and understanding of the subject matter underlying many kinds of applications. Just as business corporations will have to keep adjusting to new needs, most individuals will have to continue to acquire new skills and knowledge throughout their lives.

- The high levels of uncertainty involved suggest that changes are desirable in the approach taken when planning for new or upgraded information systems. Instead of developing long-range plans based on detailed forecasts of the future information environment, short-range (2–4 years), incremental, action-oriented plans may be more appropriate if guided by (but not tied to) a general long-range vision. To support this approach, skills in rapid implementation of limited incremental plans will be valuable. An associated critical skill will be ability to differentiate between technical and other systems capabilities that are largely "hype" and those that are truly "ripe." This differentiation will help assure that programs selected for rapid implementation represent realistic targets.

- The combination of various overloads that make large demands on workers' time and skills and the continuing need for extensive learning by all involved with work that has high information content suggest that a critical requirement for gaining relief is making the source of the problem part of its solution. Possibilities exist for extensive and better use of computers as aids in efforts to lighten some of the major burdens faced. Computers will therefore tend to be increasingly integrated into operations by individuals and organizations.

- In effect, computer skills are well on the way to becoming a key component of literacy in the future. One major difficulty, however, is that the educational system responsible for training in basic literacy is ill-prepared, both financially and in terms of staff skills and training, to incorporate that new component into the training task. Although computers are already deployed in public (and other) schools, the ratio of computers to students remains small, which makes the role of this equipment special. Almost never in a public school does every student have sole use of an appropriate type of computer, nor are computers fully integrated into the curriculum. Computer use offers an example of technology (largely because of cost and limited useful life) not yet "ripe" for mass use in early education—a situation that, over time, is bound to change.

Related Publications

The thinking presented in *At the Heart of Evolving Literacy: A Framework for Action* is part of the author's continuing and developing study of issues in the area of computers and literacy. The following are the author's earlier works on this subject published by the Program:

Electronic–Print Competition: Determinants of the Potential for Major Change. Originally published in 1989, this was later included as a chapter in *Mastering the Changing Information World*, edited by Martin L. Ernst (Norwood, N.J.: Ablex Pub. Corp., 1993).

The Personal Computer: Growth Patterns, Limits, and New Frontiers (Cambridge, Mass.: Harvard University Program on Information Resources Policy, P-91-6, October 1991).

Users and Personal Computers: Languages and Literacy, Costs and Benefits (Cambridge, Mass.: Harvard University Program on Information Resources Policy, P-93-1, January 1993).

Computers and Literacy: Redefining Each Other (Cambridge, Mass.: Harvard University Program on Information Resources Policy, P-94-5, August 1994).

Shaping the Nature of Future Literacy: A Synopsis (Cambridge, Mass.: Harvard University Program on Information Resources Policy, I-96-3, September 1996).

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Part One

The Challenges of Rapid Change

Chapter One

What It's All About

1.1 Aging Concepts in a Field of Growth

This report is concerned with information, technology, education, literacy, and with the prospects for work, recreation, and life in general. It emphasizes the dynamics that relate these subjects and certain of their consequences. In the late 1990s, the rapid changes arising in all the topic areas are having major influences on all important personal, business, and social functions. The purpose here is to review and clarify the operation of the dynamics; to examine their consequences, emphasizing those that impact on the main issues that must be faced; and to suggest steps that may be needed to survive effectively in the emerging information environment.

Why the concern with these particular subjects? Why do they merit special study at this time? The answer is simple. The United States makes continuing investments, measured in billions of dollars annually, preparing its inhabitants for life, work, and social participation. An important part of this investment is devoted to formal education, including training in literacy—that is, training in how to find, use, and communicate information. Most other developed nations are in a similar position. Literacy and early-life education programs are based largely on concepts and practices that were developed in the late nineteenth century and have changed rather little since then. There is growing recognition that the educational system is becoming obsolete in many of its features, and, at the same time, there is no strong consensus on what is required, or even on what is or will become feasible and when.

These days new technologies are greatly reducing the unit costs for all kinds of information operations—creation, movement, storage, access, manipulation, and presentation. As a result, information is becoming a larger component of all important economic and social products and services. The resulting changes touch all aspects of life—employment opportunities and work practices, personal security and national defense, social belonging and means for participation, recreation, and much more. This report is intended to help fill gaps in the knowledge that must be widely shared before deciding how to move to effect appropriate changes in how people prepare for the new patterns of life. The economic and cultural stakes involved are great, as are the potential rewards of successful actions, both for individuals and for nations.

There are, of course, forces operating to inhibit change in the areas under study. For example, literacy and education are very political subjects, with many elements embedded deeply in culture. Proposals for significant change are likely to prompt strong emotional reactions. A simple, almost homely "what if" can illustrate this point: given a means that would make personal computers (PCs) available to all people, with all the computers equipped with Spell Checkers, does time spent in school learning to spell serve any purpose once a starting level has been achieved?

Regardless of one's answer, a sense of discomfort is likely. Spelling is a key element of traditional elementary education. Spelling has always been studied; it's a hallmark of literacy and of being well-educated; major spelling contests extend to the national level, where they command massive media attention; and on and on. Yet it seems clear (as discussed in **Chapters Three**, **Four**, and **Eight**) that there will be many new subjects that will have to be learned, and the time to do so must come from somewhere. Education curricula, in general, are full of conflicts about how best to use the limited time (and funds) available and about which skills to keep in curricula and which to drop in order to respond to other needs. Because each conflict is likely to have ardent supporters of almost every possible point-of-view, allocation of time can rival allocation of economic resources in the demand for constant, creative attention.

1.2 Driving Forces and the Volatility They Build

The difficulties described above cannot be ignored; the dynamics of work, recreation, and life are steadily being fueled by major technical advances in digital electro-optics. These advances have led to dramatic changes in the tools available for dealing with information. Interactions resulting from the changes have reached what amounts to a critical mass, so that the overall process now is self-reinforcing.

There has always been a kind of cyclical pattern in the ways that the tools people employ undergo changes over time. As new technologies become available and new materials are found or produced, possibilities for new tools or for new versions of existing ones arise. If there are economic uses for these tools, they will be used; and their use may, in itself, create new opportunities for still other new tools or new versions. Thus, for a while a repeating cycle operates.

Usually, this pattern of change is slow: in periods of low technology, the scale could be measured in centuries, but in times of rapid technical change, it is much faster. In the information field, the pace in the 1990s is very rapid. More important, a rather special situation influences not only the speed but also the scale of change. Information, in all its aspects, relates to operations of the brain, and the brain is very flexible and adaptable. The new digital electro-optic information tools—computers and their "relatives"—also are very flexible and adaptable, although, admittedly, in ways very different from those of the brain.

Regardless of this important distinction, never before has this kind of flexible combination existed in the relationship between people and their tools.

The new human-tool relationship has had many impacts on the information environment. That environment has become open-ended with possibilities: of still more new tools and materials, for new formats and delivery systems, for new forms of user participation, and for new products and services generally. Personal communications capabilities have increased enormously, and their costs have been reduced dramatically. One consequence has been that many new types of global interactions among people have become commonplace. The dominant themes of the current environment, however, have been a very fast-paced pattern of change and the frequency with which situations arise in which the directions of the changes are subject to major adjustments in response to new needs or opportunities. Against this volatile backdrop, the report examines the subjects mentioned in the opening paragraph and the ways they interact in an information environment unlike any before it.

The volatility of the environment forces an emphasis on processes, rather than on fixed states. The uncertainties are so great, for example, that planning is best conducted by learning effective means to achieve steady step-by-step progress toward a goal that may be subject to repeated changes over time. This situation is in sharp contrast to ordinary practice in more stable times of developing a fixed goal, with carefully scheduled means to achieve it and only altering these plans in an emergency. Of course, even in periods characterized by the limited introduction of new technology, changes will occur in local social and economic activities, although often at a rather slow pace. Given change is the rule, it should not be surprising that there is considerable commonality among social attitudes toward major transitions in how information is created, acquired, and used, even when these transitions occurred slowly and were separated by centuries. Complaints of cultural degeneracy, voiced by those skilled in the "oral tradition" in defense against the intrusion of writing, were echoed much later by those opposed to mass education in reading and writing, and re-echoed now by concerns about youth's addiction to television violence and computer games. In some respects, this pattern should not be surprising: at any given time, decisions concerning cultural matters (including education and literacy) will involve compromises between technical and financial capabilities and more slowly changing popular attitudes. Even during periods of (historically) rapid change, and in cultures that are relatively welcoming of change, compromise dynamics will operate. At a maximum, the pace of adjustment will be set by the speed with which people can change; and this limitation implies that a full generation or more is needed for some types of change. These characteristics make the area of study relatively rich in historical analogues.

1.3 Old Words for New Ideas

Before proceeding, it is important to note that among the victims of major social and technical changes are the meanings of words; what appears at one time to be the clear and stable meaning of a term loses this identity and disappears or acquires a new meaning. In spite of their recent adoption, terms referring to one of the main sources of the current action—that is, digital computers and their many electro-optic relatives—have already suffered from such shifts. In the late 1980s, the term "personal computer" had a fairly distinct meaning. By the mid-1990s, significant computing power had been packaged in such a wide variety of devices that the term became ambiguous. Was it a PC or a "Smart TV"? An "Intelligent Telephone"? Can an Electronic Pocket Notebook device also be a PC? What about an automobile satellite navigation system? The potential list of these kinds of definitional questions is almost endless.

The matter is not critical so long as the meaning used in a given report is clear. The terms "computer," "PC," and "computer-driven" as used here always refer to devices that incorporate significant capabilities to accept, manipulate, process, and store and retrieve information (and that also often receive or transmit it) in response to actions taken by a user. These capabilities also imply considerable flexibility, in the sense that the devices must be capable of use for purposes beyond those specifically anticipated by the original equipment producer. Thus, a "Smart TV" can also be a PC (in terms of the definition used here), but not if its "smartness" is limited to matters pertaining only to receipt, storage, and presentation of television (TV) programs. Similarly, a multifunctional electronic notebook can be a PC; but one that can only list, say, addresses and appointments is not. Obviously, there will be some blurring and uncertainty at the borders of what constitutes a computer, but the intent of this definition should be clear enough for the purposes of this report. Finally, use of terms like "computers and their relatives" or "computers and associated equipment" implies a broad and inclusive range of computer, control and telecommunications equipment.

The same forces creating changes in familiar meanings of words can make obsolete issues that currently excite concern and conflict and can render mundane applications now viewed as exciting and "leading edge." During what, on any objective basis, must be viewed as a brief life span, the primary focus of computer activity has moved from ponderous, stand-alone mainframes to remote access and time-sharing; from this, to systems employing mixes of mainframes and minicomputers; then, on to dedicated stand-alone PCs, followed by on-line PC operations, and, in due course, massive PC networks and networks of networks. Along the way, additional excitement has been provided by forays into application areas as varied as Hypertext, Artificial Intelligence, Interactive CD-ROM (compact disk-read only memory), and numerous others, each briefly hyped as typifying the future of computers.

Although issues and key application areas may be transient, they can be important both for their short-term effects and for the understanding they can help people develop of the longer lasting, fundamental factors at work. So, numerous examples are noted in the report that follows, even though, in a fairly short time, many of them may seem almost quaint.

1.4 The Primary Issues

What are the primary issues here? They involve a series of related subjects of importance to both individuals and nations. As already implied, they deal with matters close to the heart of cultures, with personal and group identity, and with the ability of all types of individuals and organizations to adapt, survive, and succeed. For example:

- What kinds of personal abilities in handling and using information will be important for individuals to have in the future if they are to participate effectively in work and other social activities? Not only to participate, but to achieve a significant level of success?

- What information skills can information providers count on future customers or audiences having? What skills can they expect to be able to influence the development of?

- What skill-improving functions are best left to the family to develop? to the individual? employers? the educational establishment? different combinations of these?

- What capabilities will nations need to cultivate widely among their citizens in the future if these countries are to have healthy internal societies and not drop behind in the global competition growing so rapidly? To what extent do these requirements match those deemed critical in the past? How do they differ?

Questions like these have always been important, although conscious awareness of their importance was not widespread until the industrial revolution created a need for large work forces that could understand and make use of many types of written transaction records. More to the point, the importance of these questions has increased rapidly in recent years (as have the difficulties of trying to address them!) largely as a consequence of dramatic advances under way in information technologies. The new technologies have been changing and expanding the "rules of the game" regarding how information can be handled and used, just as they have been impacting many other aspects of life. Among the victims of this progress (like the meanings of words already mentioned) has been the traditional way of viewing what constitutes an adequate education and, still more, what will be needed in the way of individual and national competence in information-related matters.

All these points reinforce the need to concentrate on processes, rather than on a specific goal. The difficulty of doing so is partly a matter of mindset. Common practice in the past has been to view education and literacy as if they were stable subjects; this view never was completely true, and now it has become dangerously incorrect. Even the basic values and skills on which education is based will need to be reexamined repeatedly, to determine not so much whether they still apply (which, in some form, they mostly should), but how they should be expressed to be most valuable in the then current environment. What have traditionally been treated as "literacy and education problems" may, under present conditions, more usefully be viewed as "life problems."

One result of the concentration on processes is that setting firm goals in a traditional way has become difficult. A time will come when conditions are "ripe" to require a PC on every school desk in the nation. A few years later, it will be ripe to achieve another goal, then another. A reasonable date for the first target, such as "a PC on every desk," probably could be set now; but, in the long run, setting any particular target date is less important than recognizing the need to have a sense of what is ripe, what isn't yet, and what never will be within a time frame of interest. Given the speed with which the digital electro-optic "fruit" show signs of ripening, learning how to accept and install new approaches and systems quickly, efficiently, and without disruption may well become far more critical than selecting particular goals and target dates.

Put another way, the first step—and the prerequisite for further action—is to develop a more thorough understanding of what is going on, and why.

Chapter Two

Features of the Current Information Environment

A starting point for examining the questions raised in Chapter One is a brief review of the status of six areas: literacy, languages, information tools, education, the present state of literacy in the United States, and some comments on the prospects for some important aspects of life in the future.

2.1 Literacy

"Literacy" offers another example of how the meanings of words need modification in response to social and technical changes (see section **1.3**). The definition in a typical dictionary includes general terms that imply being "cultured" or "well educated" and emphasize the phrase "ability to read and write." The coincidence of the general terms and the specific phrase may have made sense when reading and writing totally dominated nonvoice communications among people over distances (and "over time"). However, that definition is inadequate if the underlying intent of the word is to be retained in the far more complex environment faced in the foreseeable future.

In this report, "literacy" is used in a broad sense to incorporate the critical skills of traditional literacy and maintains the word's social significance. Its reach, however, is expanded to include the skills needed to use the many new tools emerging from advances in digital technologies. Further, some of these tools provide support to forms of communication that depend on skills important to the oral traditions which prevailed in the prewriting era; these skills also are subsumed into the expanded sense of literacy. The result is that literacy is viewed here as comprising the following combination:

- **knowledge** concerning the nature of languages—that is, an understanding of their functions, capabilities, and limitations and of the problems associated with their use, and

- **skills** in employing the more effective tools available for expressing languages, in a given society and at a given time.[1]

With this definition, literacy covers the full range of skills devoted to the ***processes*** of communication, using all the widely accepted and relevant means available to the communicators. Knowledge of the ***context*** of the situation, and of the ***substance*** being communicated, are still critical if the literacy skills are to be used effectively, but the specifics of these subjects are treated as separate from the general domain of literacy.[2]

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[1] This definition is very close to the theme developed by Robert Pattison in *On Literacy* (N.Y.: Oxford Univ. Press, 1982).

Abilities related to literacy (for example, rhetoric, reading, and writing) have always been important and beneficial to those who possess them, because they offer: improved means for communicating effectively with others (especially one's peers), a stronger sense of social belonging, and greater perceived status. More important in a social context, the elements of literacy are highly valued, because ever since the invention of printing they have offered the principal means for investigating and acquiring most useful kinds of stored knowledge, as well as for enjoying many means of entertainment. These features of literacy have led to a "learn to read, then read to learn" concept, which has sometimes been viewed as a guiding principle for providing general elementary education.

The definition of literacy used here implies that the practices of literacy evolve as new tools are created and brought into use. Society's current concepts of what kinds of tool-using abilities are needed for one to be considered "literate" were developed, for the most part, to meet the social and economic needs of industrial advances during the years 1850-1950. The availability of the new information tools of the current age are both making obsolete and supplementing the practical value of the traditional views of literacy, but new concepts of what it means to be literate are only slowly emerging—and even more slowly being accepted and implemented in education programs.

2.2 Languages

Languages are based on:

- **vocabularies**, which are sets of symbols that represent different objects, actions, intents, concepts, etc., and

- **grammars**, which provide the conventions used to structure arrays of vocabulary elements and to provide emphasis and other nuances, in order to produce meaningful information in context.

Languages can be expressed in many ways and by employing different "tools." All human vernaculars are fundamentally oral languages; in this basic form, they rely on transient auditory signals created in the throat and mouth. Essentially the same information substance can be expressed in visual form, as durable written or printed text or, more transiently, on electronic displays. For some purposes, the same sensory receptors can be used to receive nontextual information in a variety of forms, such as music, visual or audio signals, graphics, and video.[3]

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[2] In general, while the traditional definition of "literacy" emphasizes ability in reading and writing, its everyday use has broadened until now it commonly refers to general competence, and ability to use this competence, in almost any subject area with a large informational content. Thus, increasingly references are encountered to "mathematical literacy," "science literacy," "environmental literacy," "gospel literacy," etc. This pattern of usage provides a means whereby specific knowledge of substance becomes associated with the term, in contrast to (or supplementing) the approach used here.

"Language" is another word used here in a very broad sense; it may be applied to any system that employs relatively stable, structured sets of symbols to transmit meaningful information to others, regardless of whether these others are people, hardware devices, or a combination of them.

With regard to the status of languages, historically very few people had significant interest in any languages, other than human ones, until PCs became popular in the mid-1980s. Learning human languages was viewed favorably and could be useful to individuals in a variety of ways, but means to "communicate" with devices were either transparent to users, as in the case of driving automobiles, or the province of highly specialized technical people. This situation has, of course, changed dramatically. Languages, many of them devoted to communication between people and devices, have grown in many ways—in number, variety, utility, structures, purposes, among others. They are packaged in a variety of ways, sold widely, often have global use, and have made vast fortunes for some of their creators. Acquiring skills in the use of an appropriate set of languages, keeping those skills up-to-date as the languages change and grow, and expanding the set to meet individual needs are among the major challenges facing people who seek to participate, and be successful socially, at work and at home.

2.3 Information Tools

Information tools, as the term is used here, are physical devices to enable or assist in the performance of information-related functions—that is, in the expression and use of languages to create information, move, receive, store, and process it, etc. Tools can be as simple as quill pens or as complicated as computers, as general-purpose as the human voice or as specialized as a slug of type. The possible functions, and the processes controlled by a given tool within one or more functions, can be equally broad in scope.

The original expression of language was oral (see section **2.1**), and the tool for creating sound patterns was a physiological one—the human throat and mouth. The resultant output was transient and available only locally. Since then, a long series of tools and processes have been developed in search of ways to incorporate one or more of three attributes into the means used to express information:

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[3] The use of senses other than hearing and sight are not be considered here, even though smell and touch can be of major importance for some types of communication between people (and may find significant roles in future virtual-reality presentations). Also worth noting, these senses are widely used for communication among nonhuman life forms.

- greater endurance over time,
- faster movement over extended distance, and
- improved ability to modify, supplement, replicate, enhance, and otherwise process information.

Until recently, a structural barrier limited what could be done. The barrier arose from an internal contradiction among the three desired attributes: endurance requires the symbols that comprise information content to be represented physically with very durable carriers, or "tokens," as they are called here,[4] while the other two attributes are best met using tokens that, at least temporarily, are transient and easily moved and modified. The power of digital electro-optic techniques derives in large part from the capabilities they offer to transform information symbols rapidly and easily back and forth among different types of durable and transient tokens.

The ability to change types of tokens is one example of the flexibility of the new digital electro-optic tools referred to in **Chapter One**, but that is only part of the story. Computers are, in effect, nothing less than general-purpose "information tool holders and interface devices." In the hands of users, they can be converted with application programs into any of an essentially unlimited number of specialized information tools (including a variety of tools, or tool components, for conducting changes in the types of tokens in use). It is as if a carpenter had a special device that consisted of a handle with some buttons on it: by pressing the buttons correctly, he or she could make the device become a saw—or a hammer, or a drill, or a staple gun, or sandpaper, or glue, and on and on.

Some of the most powerful new tool capabilities are devoted to information processing operations. The results have been large gains in capabilities dependent on the attribute that previously posed the greatest barrier to progress: acceptable durability has been available for centuries, as print on parchment and then on paper; and useful (although relatively high-cost) means of high-speed communications over distance were achieved with fairly primitive electric and electronic devices, starting in 1842 with telegraphy. For many kinds of operations, however, tools with adequate processing power had always been lacking. This deficiency made most types of changes and corrections to tokens using durable materials difficult and expensive. It also limited the use of many kinds of analyses (such as with spreadsheets, simulations, and a variety of computational techniques) and operations (for example, for reservations and credit card systems); and it made the use of many other kinds of applications (e.g., high-speed data compression, as used with facsimile) impossible or impractical.

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[4] For a more complete discussion, see Martin L. Ernst, *Computers and Literacy: Redefining Each Other* (Cambridge, Mass.: Program on Information Resources Policy, Harvard University, August 1994, P-94-5). See also Ernst et al., *Mastering the Changing Information World* (Norwood, Mass.: Ablex Publishing Corp., 1993).

All this has now changed—and will continue to change. Processing power has the potential to open up a wide variety of new ways for communicating, analyzing, and presenting information. It already has changed the structure of industries by making feasible what used to be impractical—and it will do so again. It has changed working habits and relationships, and will continue to do so. Power combined with flexibility already has the potential to make computers operate almost like partners in many important situations. A steady flow of improved applications and totally new kinds of computer uses can be anticipated.

2.4 Education

The purposes of education involve both the socialization of students and their acquisition of knowledge and skills important to their futures. With these goals, it is not surprising that the structure and content of a nation's education programs tend to be highly political. In most advanced nations, the goal is to provide universal education in order to nurture a population that (1) shares a wide range of social and cultural values and (2) possesses the competencies needed to compete effectively in global economic activities. The usual process for achieving this goal can be described in terms of three main components:

- Training and experiences related to literacy to achieve a "starting level," such that the tools of literacy can begin to be used to acquire other types of knowledge and skills, including those that can lead to attaining higher levels of literacy.

- Lessons and experiences intended to encourage acculturation of students. This involves their acquisition of an understanding of the attitudes, traditions, value systems, and operating procedures on which a given society is based, so that the students are positioned to become what that society considers "good" citizens.

- Provision of knowledge, training, and experiences that can prepare students for future employment. Occurring relatively late during education, and tending toward considerable specialization as the date for starting active employment approaches, this component seeks to prepare students for useful and rewarding economic roles in society.

Although there is great variability among nations (and, in the United States, among states) in almost all aspects of education curricula and operating procedures, most public education systems lag behind changes in the outside world. In large part, this is almost necessary; school systems are viewed as educating students "for life," so rapid response to what may be transient trends doesn't make sense. But in a period of continuing, rapid change, education "for life" may have to take on a different meaning from its current one.

2.5 Literacy Knowns and Unknowns

Almost all formal studies and tests of literacy[5] have treated literacy in terms of performance achieved on text-based communications and transactions. Most attention has been focused on measuring the sizes of the populations occupying the lowest levels of textual literacy—what might be termed the "survival" or "basic function" levels. This emphasis derives from the political and social goals for education (see section **2.4**); in many respects, literacy tests appear to be conducted mainly to determine how well these goals are being met. Matters related to higher levels of literacy are seldom either studied or tested directly under the rubric of literacy. As Carl F. Kaestle commented in 1985: "In view of the pervasive achievement testing that existed in schools by the 1930s, and educators' growing concern about functional illiteracy, one would think that the history of higher-order literacy skills over the past 50 years would be familiar and precise. On the contrary, there is almost no historical work on the subject."[6] The net effect is that the entire subject of higher levels of literacy is left to a kind of self-definition and self-policing by the more prestigious higher educational institutions of a nation.

Only recently has this situation begun to change. In 1988, George Miller published a general review article on literacy and its status,[7] which employed a traditional definition of literacy but included materials on the scientific knowledge available concerning the underlying skills and mechanisms critical for improving literacy. In 1993, the first results from a U.S. National Adult Literacy Survey were published.[8] While largely in a traditional mold, this document covers a range of literacy capabilities, defined in five ability levels, and includes materials that illustrate specific differences in skills characterizing the various levels. The survey results presents detailed statistics on responses and on many attributes of the sample populations, and it provides detailed examples of the study instruments employed.

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[5] In this section, the word "literacy" is used with its traditional meaning.

[6] Carl F Kaestle, "The History of Literacy and the History of Readers," *Review of Research in Education* **12**, edited by E. D. Godwin (Washington, D.C.: American Educational Research Association, 1985), Chapter One, 32.

[7] George A. Miller, "The Challenge of Universal Literacy," *Science* **241** (9 Sept. 1988), 1293-1299, 1293.

[8] I. S. Kirsch, A. Jungeblut, L. Jenkins, and A. Kolstad, *Adult Literacy in America: A First Look at the Results of the National Adult Literacy Survey* , a report prepared by the Educational Testing Service for the National Center for Education Statistics (Princeton, N.J.: ETS, 1993).

The traditional pattern of literacy studies appears to have been breached, but the traditional attitude toward what constitutes literacy remains for the most part in place.

2.6 Life Prospects: Information, Economics, and Work

When the Industrial Revolution was at its peak, during the latter half of the nineteenth century, the majority of the world's population felt few direct impacts from the changes it was causing. Indirect impacts, however, were enormous; the nonindustrialized nations and their leaders operated increasingly from positions of relative weakness and often were forced into a colonial or dependent status. But as individuals, people mostly lived much as their ancestors had and shared little in the greater affluence, health, security, and opportunities available in more developed countries. The catch-up process for many nations started seriously only as the Industrial Revolution tapered off, in the mid-twentieth century, and a new revolution started. For some, such as the newly independent nations of the Pacific rim, this situation offered an opportunity to make rapid advances and to join those already in more favorable positions. For others, the new revolution may simply increase their problems and force them to drop further behind.

The relationships between the successive revolutions can be described in terms of the diagram in **Figure 1**.[9] The Industrial Revolution was fundamentally an Energy revolution. Although it produced a voracious appetite for material resources of all kinds and required increasingly sophisticated managerial, technical, and social information support to keep advancing, favorable energy supplies were key to starting the revolution and were an underlying reason for the need for many other types of resources.

Energy resources in use offer a striking measure of the magnitude of changes that arose. At the start of this revolution, the per capita energy resources available to a community in an economically successful country (i.e., an "advanced" country) were few and small: a share of the human "muscle power" of the community, a share of its limited draft animal power, perhaps wind or water power, and wood-based heat energy for comfort, and some forms of materials processing. The total share may not have exceeded a horsepower or two. By any measure, the nonhuman energy would be very expensive and mostly available only to a small fraction of the population.

When the revolution had run its main course, say by the 1960s or '70s a community in a an economically advanced country would have a hundred or more horsepower per capita available, in many convenient forms and used for many purposes. This energy would have

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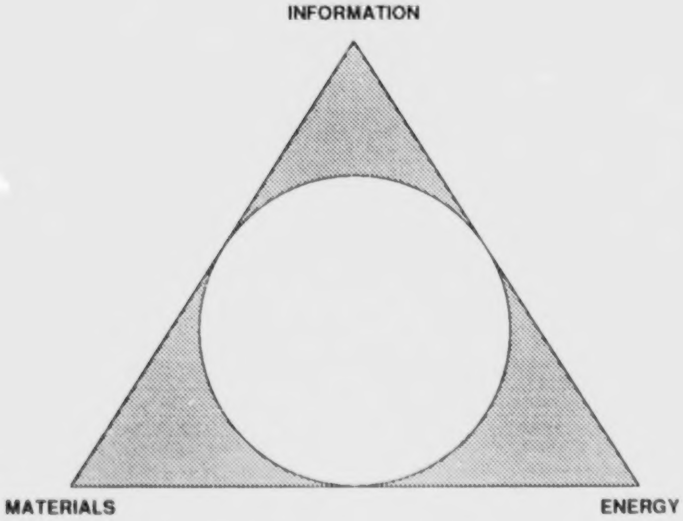
[9] This diagram was used for many years by the Harvard Program on Information Resources Policy (PIRP), to help describe its mission.



- Without materials, nothing exists
- Without energy, nothing happens
- Without information, nothing makes sense

Figure 1

What It Takes to Do Something

been very cheap and widely distributed among the population. Finally (and largely because the Information Revolution was already underway), the processes employed for most energy-intensive uses would have become far more efficient than was possible in previous periods.

A similar pattern is already emerging for the current (very incomplete) Information Revolution. Before rapid advances in digital electro-optics started in the 1950s, the primary information resources available to communities in advanced nations included postal, telegraph, and telephone services and mass media in the form of written publications (accessible through libraries as well as by purchase), movies, radio, and television. For use by individuals, only the lower bandwidth, fixed-site communications mechanisms, such as telephone and postal services, were economically and widely available. With a few (usually subsidized) low-speed, low-capacity exceptions, unit costs for all personal, nonpostal communication operations were high.

As the Information Revolution has proceeded, individuals have acquired: a wealth of powerful processing tools, both simple and sophisticated; associated high-capacity storage and access systems; and an enormous range of new capabilities for broad-bandwidth global communications. Impossible, "ideal" systems of the past are now easy to build—and then supersede! More important, the whole information environment continues to open up to new possibilities. Accompanying all this change, the unit costs of all information operations have plummeted.

The economic consequences of change have been profound. Because information has become much cheaper (as well as more timely, more detailed, and more accessible), it has been substituted for other production factors in activities such as the following: the design of products and services (to offer more capabilities and uses, more availability, quicker operation, greater reliability, less weight and size, etc.); the management of businesses (through better control of scheduling and operations, better inventory and cost control, better geographical coverage, improved marketing based on better data, extended customer services, etc.); and a host of others.

Not surprisingly, there is a price for these benefits. As the Industrial Revolution proceeded, it became harder and harder for a worker to sell "the strength of his back." Similarly, skills such as those of a clerical worker performing routine operations are now rapidly losing value in the marketplace. The big growth areas are in information-related fields, including recreation and entertainment as well as the more workaday applications concentrated on in this report. Although many of the new information-based job opportunities may not require much feel for the use of PCs, it seems unwise for either individuals or nations to rely on this view as a basis for planning a successful future. The Industrial Revolution left people out, for reasons of their taste, temperament, or lack of opportunities to develop and practice the needed skills; the Information Revolution will do the same. Lack of opportunities can, one hopes, be made the least of the reasons for failures.

Chapter Three

Everything About Information Is Changing—and Fast

The accepted views of the topics discussed in **Chapter Two** are being subjected to the direct and indirect impacts of a variety of (almost violent) changes in the world of information, largely owing to the introduction of a wide range of new products and services based on digital electro-optic techniques. The major changes are summarized below, from the viewpoints of those actively involved—that is, the creators, recipients, and users of information. Many items shown here are amplified and placed in perspective in the remaining chapters.

Table 1

Changes and Their General Consequences in the Information Environment

Nature of Change	General Impacts
1. **Information Quantity** The quantity of information easily available to individuals, and often forced on them, has grown enormouslyboth at work and for personal work and recreation at home.	People can access more information and have more information (requested or unrequested) routinely delivered to them for use in all aspects of their lives. The information varies widely in quality and can be very duplicative in content. Recipients often are required, by various circumstances, to examine, filter, and selectively absorb and use more of this growing supply of information than previously was necessary.
2. **Information Quality** The quality of widely available information has improved in terms of timeliness, detail, accuracy, and means of validation.	For competitive and bureaucratic reasons, creators of both local and widely distributed information are expected to meet higher standards in the attributes listed in the left column.
3. **Information Structure** The very nature of information items is changing as more and more of them are being designed for users to interact with in some way, rather than being only passive recipients.	Again, for competitive and bureaucratic reaons, user-recipients will need to develop appropriate interaction skills to get the most out of some kinds of information they can now access or receive. In the preocess of intreraction, they often may need to become partly user-creators.
4. **Authorship and Publishing** The interactive capabilities described in 3, above, permit easy joint or group authoring and widespread formal and informal publishing, characterized by the use of both traditional and new types of formats. The result can be reports never formally completed and published without a full list of participating authors.	Numerous new types of formats are being employed, and even more are being tested. Authoring and small-scale publishing are being democratized. The roles of older formats (e.g., printed newsletters, scientific journals) are being altered; less reliance is being placed on them, even in situations where they maintain their traditional markets.

5. **Information Analysis** Helped by powerful new computer processing capabilities, techniques for analyzing information have become more varied, more effective, more sophisticated, and more automated at the price of becoming inherently more complicated.	For competitive and bureaucratic reasons, user-creators of work-related information must develop greater analytical skills than were needed in the past. User-recipients must improve their abilities to comprehend, evaluate and interpret received analyses.
6. **Presentation Quality** New tools are helping to improve the quality of presentations of information. Quality can involve the use of better layouts, more graphics and other visual elements, more uses of color, more linkage indicators, means for three-dimensional viewing, dynamic displays, structured use of many types of media in a single information item, and more user control of all of these features.	Once more, the same reasons will tend to require users and creators to respond to what have become new presentation standards. In addition to user skills in evaluating and interpreting all the types of received presentations, the creator must acquire greater skills, or support resources (including computer resources), or both, to prepare high-quality information for distribution.
7. **User Demographics** The geographic and demographic boundaries of those interested in a given subject, and able to participate and interact concerning it, keep expanding.	Both creators and users of information must develop greater skills in relating to and communicating with more and more people over greater and greater distances and sometimes across languages and cultures.
8. **User Tools** New types of information tools, such as PCs and related digital electro-optical devices, are becoming absolute necessities for all who make extensive use of information at work or at home.	Both for individuals and at a national level, economic competitive forces and personal life-style interests are requiring increasing numbers of people to become comfortable with the various new tools. Attaining this comfort requires them to have the skills needed to operate and exercise relatively sophisticated control over these devices.
9. **Tool Complexity** The new tools are rapidly growing in power and in range of application; they are also growing in inherent complexity, although much of this is being hidden from users.	The combination of growth in complexity and hiding of complexity is common in tools intended for wide use. The balance between these characteristics depends on many factors, and the eventual tilt will influence both future markets for PCs and their social impacts.
10. **User Responsibilities** The highly interactive nature of the new tools, their growing sophistication, the need for personalization of their more advanced applications, and their growing application to important functions of personal life necessitate a correspondingly large increase in user personal responsibility concerning all aspects of acquisition, use, and retention of work and personal information.	Although experts can assist the less skilled in many ways, users will have to make some critical decisions personally. These decisions can be very idiosyncratic, and usually will involve such items as inputs and controls for operating particular applications. The ability to make good decisions in these areas can require personal knowledge and skills regarding the uses of languages with many features similar to those usually associated with traditional concepts of higher levels of literacy.
11. **Employment Changes** Largely because of the pace of technology and the growth of a global economy, the nature of employment is changing worldwide. Stability and security are disappearing in a cloud of uncertainty about which skills in which local industries, if any, will retain value over time.	Past expectations of stability in the value of occupational and professional skills encouraged a view that education for life employment could be mostly a one-time affair, with normal job experience being adequate to maintain these skills thereafter. The new situation calls for deliberate continuing education, if one is to avoid obsolescence; and this education

	should include gaining a higher level of skills than was needed in the past with regard to both using received information (comprehension) and preparing information for others (being comprehensible).
12. **Education Needs** In the face of what will probably be a much greater need for better education, computer-based tools are poised to assume a major role supplementing and extending traditional education methods. This capability derives from a host of technical advances that enable better user interfaces, easier user-machine interactions, and more effective presentations (including multimedia).	Assuring that full advantage is taken of the growing capabilities of computer-based education methods may be critical to coping with the other changes described above. In the process, a fresh look at what is meant by literacy, and what role achieving different levels of literacy should have in our educational system, seems well merited.
13. **Continuing Change** Technological advances appear likely to support a continuation of the rapid pace of change for at least several decades. Further, the past record suggests that the directions of major future changes, and the nature of the future tools that will have the greatest value, cannot be forecast with any accuracy. Finally, although some of the changes are leading to standardization and simplification, others favor greater complexity and uncertainty; the balance between the two movements is uncertain.	There is no promise of early stability in sight!

Chapter Four

The Treadmill of Pressures for Investment

The changes described in Chapter Three pose major challenges of many kinds. What are the critical problems that must be faced when developing measures for dealing with the impacts of these changes?

4.1 The General Challenge

The most significant problems people will have to deal with are by-products of the advances arising in digital electro-optics and allied areas. These advances have made it both practical and inexpensive to build many new forms of equipment for conducting all types of information operations. The new capabilities have helped overcome a host of limitations on what could be done with earlier technologies, but, at the same time, they have created new requirements for users (see **Chapter Three**).

The most fundamental new tool to be mastered in the late 1990s is the PC (using this term in the broad sense of **Chapter One**), with its associated peripheral equipment and software. Use of PCs requires learning the special languages needed to control them; and using the tools well requires understanding whole families of new concepts concerning presentation, interaction, and analysis of information. In the process of learning and gaining understanding, the practical conception of what constitutes a working language is being changed and expanded to incorporate new features. Older language skills, such as rhetoric and composition, will continue to have great value, but mainly as elements in what will evolve into a far broader context in which to view language and literacy.

4.2 Investments

From the point of view of individual people, there are two broad categories of investments that will have to be made in order to master the new tools and succeed in the new information environment that is developing:

- **Investments of personal time and commitment** to learn how to use the new tools as they grow in number, type, and areas of use. In essence, this involves not only initially mastering the use of PCs but also extending these skills (and occasionally relearning some of them) in order to maintain this capability as technological progress forces continuing changes. This investment includes learning how to select, set up, personalize, and properly use appropriate application programs and their successors over time.

- **Financial investments** (to the extent these are not provided or subsidized by employers, schools, etc.) to acquire and maintain hardware, software, information access charges, supplies, and, as needed and available, formal training for conducting personal operations.

Because this report is primarily concerned with the future needs that individuals will have to deal with directly, the main focus is on the first category—the required ***personal investments*** in learning and ***allied social investments*** needed to make the personal efforts practical and efficient. The personal requirements also have two main components: acquiring substantive knowledge and learning a number of computer-specific skills.

4.2.1 Substantive Knowledge

This component concerns acquiring appropriate background on the subjects and techniques to which specific computer applications are devoted. For example, if computer applications of interest concern certain statistical techniques or simulation operations, it is important to have a general understanding of these subjects (i.e., their conditions of applicability, their capabilities, their limitations, etc.), independent of their specific instantiations in particular computer programs. Thus, the elements of this kind of knowledge usually can (and sometimes, but not always, should) be described and learned as subjects in themselves, largely independent of the detailed capabilities of specific application tool(s) with which the knowledge will be applied. This kind of knowledge can be critical to intelligent use of many kinds of computer tools.

The effort involved here will vary greatly across specific applications and intended uses. At one extreme, for subjects such as simple wordprocessing of familiar types of documents (for example, personal letters), the effort will be minimal; the needed substantive knowledge will probably already have been acquired through experience or prior general education. At the other extreme, if complex analytical tools (such as the advanced statistics or simulations mentioned above) are to be employed, major learning efforts may be needed.[10] But the most important feature is that the total effort can become very large. Although people may not need to become smarter or wiser than they are now, they will need to know much more about many more things!

Part of the new substantive knowledge will be concerned with new types of equipment and services (usually incorporating some form of computer control) for managing a wide range of work, household, and entertainment operations. Although producers will try to keep consumer requirements simple, which should mean that few of the learning tasks will be very complicated, there can be large numbers of them and frequent changes in the control practices employed. To illustrate the situation, the VCR control instructions of the early 1990s, which tended to change frequently and baffle many adults (but few children), can be regarded as just the starting point for what may be coming on a large scale! Some proposed future systems, like one to offer 500 video channels, may require completely new design concepts of appropriate means for customers to use and control the equipment.

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[10] For some new computer-based applications and formats, the desirable substantive knowledge is itself incompletely developed—the subject matter of the applications is simply too new. Examples include interactive multimedia and virtual reality, where most commercial efforts amount to experimentation to learn what will be effective.

A much larger component of the growing knowledge requirements, and one with more serious implications for the individuals involved, arises in the work environment (both job-related work and work devoted to home activities). Here, computer capabilities are steadily being put to new uses that bring with them the need for associated substantive understanding. A very simple example can illustrate the process. As a result of the development of computer graphics programs, there has been what amounts to a "deprofessionalizing" of much business graphics creation. Organizations have come to expect most or all their staff to be able to design and produce the bulk of the graphics needed for presentations, reports, sales calls, and the like. As a result, professional artists are being used only for the most important and most public situations. Thus, graphic skills can now be important to the careers of groups of workers who previously regarded these skills as outside their areas of concern. This example deals with skill levels that, in the mid-1990s, could for the most part be kept rather simple. Far more difficult requirements might arise in the future, as advanced presentation techniques are introduced. Following this type of pattern, requirements for new types of knowledge and skills in other areas are growing rapidly in both numbers and levels of complexity.

Other requirements may derive from changes in social practices, which, beginning in the early 1990s, started moving more (and often new types of) responsibilities from institutions onto individuals. These include, for example:

- Fairly complex financial planning operations, as traditional company pension plans are being replaced with IRAs, 401k's, and similar kinds of arrangements, which often place more responsibilities on future workers for managing the investment of their retirement funds.

- Personal health management, through personal access to and evaluation of information from medical data sources, to help individuals ensure they are getting the best care available from a given Health Care Provider.

- Effective use of computers for rapidly growing home-shopping activities, including not only general merchandise goods, of the kinds already offered by mail and phone, but also direct acquisition of complicated types of entertainment and travel reservations and the purchase and sale of financial instruments. In general, there are appreciable savings available to skilled users of these systems.

As is frequently the case, analogues to these kinds of requirements existed in earlier periods. One example was the expectation that most people would be able to understand and cope with a variety of kinds of written instruments (schedules, bills, money orders, and rules and regulations, etc.) that arose as universal education became available. These requirements may seem simple now, but they probably weren't considered simple by those first affected by them!

4.2.2 Computer-Specific Knowledge and Skills

In many respects, the efforts required for the computer use components of the items discussed in section **4.2.1** amount to learning a collection of new languages. Each language is devoted to performing a specific application or function that must be understood adequately by the user, and all the languages are concerned with the process of issuing codes that provide instructions to a computer. The codes are expressible in a variety of ways—with a keyboard, with a computer "pen," with a pointing device (e.g., a mouse), by voice (although still somewhat clumsily), or by a combination of these. For major applications, languages of sizes on the order of 500 to 600 possible commands are common; in extreme cases, almost ten times that number may be available.[11] Although these "commands" are not quite the equivalents of "words," the range in size can be partly evaluated by noting that it is not much smaller than the minimal vocabulary of a usable spoken language (as illustrated by Basic English, which has 700 to 800 words).

Gaining a high level of understanding of a collection of application languages is no small task, but it can be eased somewhat by using the computer itself to help learn how to use new applications (see **Chapter Nine**). Moreover, because the focus of this report is on subjects of national—and global—scope, only certain kinds of applications are directly important here. Eventually, uses for computers will be found in essentially all aspects of human life, but many of them will be highly specialized and will influence only small segments of the population. The topics important here, however, are those that have impacts and interactions at the national population level. This criterion can be used to narrow the areas needing attention, since it eliminates efforts that must be devoted to learning most of the specialized application languages.

On the basis of that criterion, the application families of greatest importance to "Basic Computer Competence" become those that combine most of the following:

- Those that have mass markets for direct uses by individuals, thereby influencing large populations.

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[11] The *Wall Street Journal* noted that Microsoft's Office97® program has some 4,500 commands; see Don Clark and David Bank, "Microsoft May Face a Backlash Against 'Bloatware,'" Nov. 18, 1996, B1.

- Those sufficiently important to their users that considerable investment of effort in mastering their use is justified.

- Those dealing with purposes that encourage extensions in scope and detail until their inherent complexities, and the sizes of their command languages, are significant.

- Collectively, those with enough worthwhile uses in a wide variety of formal and informal work situations and significant home activities so that personal computer literacy skills will not be left behind at the office when workers return home—as they frequently are at present.

The price paid for this narrower focus is a definite distinction between Basic Literacy and Higher Level Literacy. The basic level requires computer-specific knowledge adequate to make effective use of a limited set of applications (and even these may be employed using only their more important features and functions). Higher levels will be associated with much broader application capabilities, extending to such a range of experience that acquisition of an additional new language becomes a minor inconvenience, rather than a major task.

As usual, there are historical analogies. Multilingual capabilities have traditionally been considered a hallmark of higher literacy, valuable not only for the ability they offer to broaden one's cultural experiences but also for the greater understanding of one's own language and culture, which is often a by-product of acquiring this capability.

In broad terms, this perspective presents the PC (and its various relatives and successors) as the key tool for working on or with information in the future, with mass uses in the home as well as the workplace and a potentially dominant role in personal development and in the practice of future literacy. To the extent that PCs do not attain such a broad role, their impacts on education and literacy will be lessened.

4.3 Complexity Dynamics

The rapid and continuing growth in capabilities of computers, and their application to a widening range of human activities, incorporates a process (see section **3.9**) common to most important new technologies. This process (which applies to both hardware and software) can be described as the management of complexity. Its purpose is to allocate the gains obtained from advances in technical capabilities in order to maintain a balance between two contending thrusts that lead to either:

- growth in the *inherent complexity* of a use or application, when the technical advances are employed to increase the performance, scope, details, and features of the use or application (i.e., by incorporating spelling checkers, means for defining table formats, and multiple font capabilities, etc., in a wordprocessing program), or

- decrease in the *perceived complexity* of the same use or application, if some or all of the increased technical capabilities are devoted deliberately to "hiding" the true complexity of the system from users (through offering a graphical user interface, improved Help comments, progress reports and screens, and simpler user personalization menus, etc.), rather than being devoted solely to improving performance, details, etc.[12]

The balance achieved will depend on many details and can have enormous impacts on all aspects of, and all participants in, information operations. Markets, businesses, governments, and individuals all have roles and all will feel the results, with technology setting limits on what can be done at any given time by establishing an envelope of product feasibilities.

4.4 How New Tools Differ

The general "complexity–complexity hiding" balancing just described has arisen in many situations where technical advances were leading to large changes in products and in the types of user involvement they required. In the case of the PC, however, the process is operating in an unusual and extreme environment. Most other examples (automobiles, radio, TV, microwave ovens, etc.) involved relatively limited ranges of product application compared with the breadth covered by computers. And growth in the technical capabilities of the relevant technologies was dramatically slower or continued at its fastest pace for much shorter periods than has been characteristic of PCs.

The fast increases in the technical capabilities of computers have encouraged rapid and continuing availability of more complicated kinds of new applications (or new and usually improved and broader versions of existing ones). The general competitive environment has placed great pressure on businesses and individual users to employ the newer applications. This, in turn, has led to rapid practical obsolescence of existing hardware and software, which poses still other problems different from those of earlier experience. In particular, although applications of most other recent types of new technologies needed only brief, sharply focused periods of personal-learning commitment from users, and little need for later retraining, computers have requirements that appear open-ended in all dimensions.

A good comparative example is the case of the automobile. A lot of complexity that users once faced has been moved under the hoods of automobiles. Users no longer need to turn starter cranks, adjust chokes, advance or retard ignitions, or shift gears. All of these advances (and many others) were easy for users to handle once they had learned the basics of driving; little new learning was needed. Further, throughout the improvement process, well-maintained old cars were always able to travel on all ordinary roads and highways.

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[12] Complexity-hiding has a cost beyond just the computer power devoted to it. Some of the simplification steps may involve making choices on behalf of users that differ from choices some users (especially experienced ones) might prefer.

PCs also have had much complexity hidden in the "box," but, in many other respects, the results differ quite strongly from those that characterized automobiles. Except when considering only very limited or dedicated purposes, the available computer applications of potential interest or value to users have grown in number, scope, and detail faster than complexity-hiding operations have eased user learning requirements. This has led directly to greater learning and relearning requirements being placed on users; and these learning needs can be expected to continue over an indefinite period of great instability.

The fast pace of change means that PC hardware and software quickly become obsolescent; after a few years, software will lack features that have become important and hardware will no longer be able to run the latest programs. The equivalent situation for cars would involve banning them from using any of the better highways once they were, say, three or four years old. Also, in the case of computers, there is no guarantee that older versions of applications (analogous to the secondary road systems for cars) will be maintained indefinitely by their producers or that older personal or business records will be transferable to newer versions of programs once a few intermediate versions have been skipped.

4.5 Pressures to Grow and Change

In contrast to most products and services, the supply of information is effectively infinite—provided one is not too concerned about redundancy, quality, demand, or any of a number of similar attributes! By enabling people to process, distribute, store, find, access, and use information more quickly, more easily, and more cheaply, computer-communications systems have opened the floodgates to that infinite supply. As people become capable of using more information, and doing more with it, excuses both good and bad evolve to encourage them to do so. The complexity of income tax records and forms, the detail of other government reporting regulations, the amount and variety of "junk" print mail, the spreading use of graphics and elaborate layouts for simple internal business presentations, the excessive distribution of electronic mail (e-mail) because it is easy to process, and the increased complexity of many types of analyses all are tributes to the effects of stimulation and growth. Although an overstatement, it is useful to view this growth as a pattern in which *if something of apparent value in the information field can be done, then legal, competitive, market, and other forces eventually will operate to turn the capability into a necessity!*

Thus, an application is developed. Competition forces it to be improved and made more complicated—more scope is added, more details, more features and functions—but also in other ways made easier to use. Some direct users, on their own or in response to those to whom they present their work, begin to employ the expanded features capabilities. Gradually, use of the features spreads until these begin to be considered requirements, rather than options. The process then starts over, as competitors or aggressive marketers press for development of still more modifications to the application—or for development of an associated new product, or both. Given that the possibilities are essentially open-ended, the cycle can continue as long as growing technological capabilities expand the feasibility envelopes of the various products.

Part Two

Languages

Chapter Five

How Languages Arise, Grow, and Change

Information becomes useful only when it is transferred in a way (and to an entity) that enables it to contribute to some form of action. The action can be trivial, as with much social conversation, or vital, as when it deals with matters of human survival. The transfer process that leads to the action depends on use of a language, expressed in an appropriate physical form, that is understood and accepted by the involved participants, both living and inanimate.

The use and character of languages are subject to influences from many sources. For example, if groups of people with a common language become isolated from one another, with little movement or communication among them, their speech (and, more broadly, their cultures) will diverge. Separate dialects will arise, then different languages, much as, under similar conditions but over longer periods of time, new species evolve.

The reverse also occurs; trade and movements among peoples with different tongues have an integrating effect, creating the need for a language that can ease problems in communicating. Sometimes an imperial language, such as Latin, solves the problem; far more often, linguae francae are created. Among people with a common language but many dialects, the same integrating influences can weaken local dialects while strengthening the use of a more homogeneous pattern of speech over a larger territory.

When new information tools are introduced, they sometimes can amplify and speed these language-integrating changes; radio and TV are examples. More significant, they can also force the creation of new, very different languages—a chaotic process, and one that has been going on directly in view for the last fifty years. In a conversation about languages a hundred years ago, there would have been only a single class to discuss: languages for oral or written communication among people. Now the subject could include at least two other classes: languages for communication between different technical devices and those that enable people to interact with devices. In a parallel way, the very nature of languages has been changed. In the earlier conversation, with very minor exceptions, only two kinds of written materials would have been covered: alphabetic text and ideograph-based materials. Now, various hybrid languages are in use, and multimedia capabilities may eventually lead to formalized new types of languages (including, perhaps, linguae francae) not yet envisioned.

Device control "languages" have been employed for many decades, but they were modest in size, specialized in use, and not readily recognizable as "languages." Automatic railroad switches, electric power-distribution controls, and telephone transmission and switching systems are examples of areas of use. As electronic devices were introduced, and their size and variety increased, the device languages also grew in size and complexity to meet the needs of systems like satellite communications and TV. But the big changes didn't arrive until the spread of equipment based on digital electro-optics; these new technologies altered the picture in dramatic ways.

By the early 1990s, digital electro-optic information processing power had become ubiquitous. The processing operations for many applications are entirely automatic and hidden from users—for example, the data-compression activities critical to economical facsimile and the packet-switching activities used in much digital communication. Under these conditions, in which most users are totally unaware of what is going on, there clearly is little or no need for special learning about the details of the operations. At the other extreme, where personal computers furnish the best example, the very objectives of the more important applications make it necessary for a person to be in control of the operations; and effective control requires learning one or more of the special languages used to issue commands to the equipment.

Finally, as suggested in **Chapter Three**, the new technologies are an important factor in facilitating globalization, because they provide critical support for how trade, travel, and worldwide communications operate. They thereby contribute indirectly to growth and changes in the natural human languages used for everyday information exchange. Thus, three categories of language are being influenced:

- those used for device-to-device communications,
- those used for person-to-person communications, and
- those used for communication between people and devices.

All three categories are covered in the following chapters, even though the last one, because it includes the instruction languages for all computer applications, is by far the most critical to the subjects of this study.

Chapter Six

Categories of Communication

6.1 Device-to-Device Communication

Device-to-device communication is of tremendous economic and social importance, although this importance is often overlooked because many of its operations not only are invisible but also take place in only a small part of much larger pieces of equipment or systems. Only when device-to-device languages are referred to by their more commonly used names—standards and protocols— are their roles more widely recognized. Under these names industrial "wars" are fought, often involving nations as well as companies, and their outcomes can strongly influence the futures of specific organizations and technical systems.

The device-to-device communications of interest here fall into two general categories:

- Support for information movement and switching networks, such as telephone, network and cable TV, on-line services, local area and wide area networks (LANs and WANs), global networks, and other similar systems. These tend to be "information substance in-same information substance out" systems (but with the "out" at a different location or in a different format). Although such operations are critical to all modern uses of information, device-device linking is usually very specialized, and few end-users need detailed knowledge about how it works.

- Support for action-producing systems, which have information substance-in but some form of specific (and ordinarily predictable) action as output. These system are, in concept, successors to or extensions of directly linked mechanical devices, such as water clocks and mechanical governors. Wide use of "symbols-in" to get "action-out" had to wait until control of electric currents became practical. Since the mid-1800s, these systems have come to dominate the scene (e.g., in thermostats and alarm systems, autopilots, automobile ignition-control systems, and many, many others).

A common element in action-producing systems is the flow of information from a sensor (when it indicates a specific type of environmental change) to an actuator, with some (and sometimes a lot) of processing in intermediate steps. The importance of this general category of device-device communication derives from a combination of two factors:

- the need in many (but not all) of these systems for human beings to enter commands (to set the thermostat, specify the flight parameters, etc.) to control the conditions that will trigger automatic processing and establish the responses that the system should make to a given change in sensor input,[13] and

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[13] To be more rigorous, all these devices need human input, but for some kinds of dedicated equipment, the input is "designed into" the device or incorporated into a factory (or maintenance-operation) setting or tune-up.

- the likelihood that increasing numbers of future high-value PC applications will require such careful, sometimes complex, user input before the PC can start an extended (or even indefinite) period of automatic operation. An example of this kind of requirement is instructions a user must provide to a PC for it to examine, filter, and prioritize items from a large, incoming electronic flow of timely and potentially relevant information.

There is a potential for some blurring of action-producing types of device-device communication and person-device communication (see section **6.3**), but there are at least some subtle differences between them: (1) Typical operations in which human-machine languages are employed usually involve continuous streams of person-device interaction while an application is in use. Almost the opposite, device-device languages tend to be employed mostly in situations in which, once instructed (in a person-to-device language), the machine interacts continuously with specified environmental sensors and needs no further human instruction for an extended period of time. (2) The computer-language component of human-device communication required to get such applications as information filtering started can consist of extremely simple commands, that take almost no effort to learn. In contrast, the natural-language skills needed to make this type of application work *well* on a continuing basis (e.g., knowing *which* words, phrases, etc., to enter to achieve the desired filtering now and in the foreseeable future) can be considerable. These language-skill requirements are almost indistinguishable from those associated with traditional literacy and quite different from the computer-application control languages needed in most current person-device situations. This pattern, in which the human-device language input is simple to learn but the human-device control setting input takes great skill to be done well, may become characteristic of many of the more useful future applications.[14]

6.2 Person-to-Person Communication

With the rapid globalization of trade and tourism and with parallel massive, continuing improvements in communication, what has been happening on the language front? Are patterns of language change arising similar to those described in **Chapter Five**?

Although these processes may still have a lot more globalization and change ahead, two aspects already are apparent:

- the emergence of what amounts to a global written lingua franca, based primarily on the American version of "English," and

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[14] The complexity-hiding dynamic can be significant with these applications. For filtering, there can be simplification, by making natural-language expertise available in the form of computer-generated questions and suggestions, etc., and complication, by adding new features and capabilities.

- the start of significant use of (often global) hybrid analog-digital extensions to common written languages.

6.2.1 Global Language

Over the last half of the twentieth century, the use of English has increased in both the developed and the developing worlds. It is the standard language of international air-traffic control, the most widely used business language (and often the official company language of large international corporations headquartered in small, non-English-speaking countries), the dominant language of scientific publishing, and the original language (before dubbing) for a major portion of the world's output of cinematic and video products. Worldwide, it has become by far the most common and most generally valuable "second language" to acquire. Its use continues to grow as the benefits of computer networking provide increasing incentives for companies with strong international interests of almost any type, regardless of where headquartered, to employ it as the effective working language for international communication.

A starting point for this status was the strong position of the English language at the beginning of the twentieth century, owing to the global reach of the British Empire and the high level of international trade this supported. After World War II, the United States became the dominant force. Ending the war with both military power and a massive, undamaged industrial base, the U.S. was able to establish a strong, politically active global position. It also benefited from both its early recognition of the potential of digital electro-optics and a strong entrepreneurial tradition. Early wide use of computers led the U.S. to become a leader in computer hardware and even more dominant in software design and production, as well as in the organization of computer networks and databases and the establishment of on-line services of all types. Finally, there was no other strong contender, and competition was fragmented by the inability of other nations to reach agreements that might have enabled another language to compete with English.

Whatever the reasons, the key points are that:

- because there are great and increasing needs for, and interests in, sharing data, information, news, and entertainment worldwide, a global language, or at least a global lingua franca, has become a practical requirement, and

- because there already is considerable inertia behind the use of English for this purpose, it would be difficult for another language to replace it for this purpose in the foreseeable future.[15]

The situation described here is the result of market-driven forces, rather than of any direct, purposeful government actions.

To understand how strong the position of English is, consider briefly the status in the mid-1990s of two very different global services: computer networking, with the Internet as an example; and satellite broadcasting, with Cable News Network (CNN) as the illustration.

- The Internet, as its name implies, is a network of networks. Originally heavily subsidized by the U.S. government and devoted to the academic research and development communities, by 1994 it was rapidly being commercialized. It also was growing quickly. For the moment, the system was retaining its very loose organization and structure, and much of its not-for-profit character, but many questions were arising about whether the system should, or could, retain its old culture in the new environment commercialization was bringing. By early 1994, the Internet served:

    - over 25,000 networks, plus limited service (mainly e-mail) to another 30,000 networks,
    - over 2.2 million host computers supporting an estimated 30 million users of all types, and
    - e-mail and other gateways in 143 countries.

  During rapid expansion of the Internet in 1992-95, its foreign growth rate exceeded the domestic rate. The Internet is by far the largest computer network structure in the world and is already an important factor in international communications. Major changes in its operations must be anticipated as its commercialization and growth continue, but, one way or another, many of its structural and linguistic features seem likely to survive.

- CNN is the largest TV news network in the world, using satellite broadcasts to reach audiences in about 140 countries. Initially, all broadcasts were in English, but plans for the future emphasize using local languages and cooperation with local services. CNN is estimated to be available to roughly one-sixth of the more than eight hundred million homes with TVs in the world, roughly 130 million homes; 60 million of these are outside the U.S. CNN experienced fast growth both in audiences and prestige during the early 1990s.

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[15] Some important caveats: (1) the uses of second languages have limits: it is hard enough for a nonprofessional to understand a simple technical manual in a native language, much less in a second language; (2) globalization can bring considerable pain to countries (and populations) with particularly strong traditions and cultures. Members of these cultures may oppose the spread in use of languages other than their own and may choose (successfully or not) to reject considerable benefits in order to preserve their language and culture (France and Quebec furnish examples of these attitudes); and (3) the prospects for rapid, computer-assisted language translation, with text or voice output, are improving. If or when such translation capabilities are available, some of the needs for a global language may evaporate.

As systems like these grow, increasing use of local languages for local reception can be expected, but the backbones of the two examples have English language origins which are unlikely to be forgotten quickly. Now and for considerable time to come, a lot of the information resources most valuable for people to access are located in the U.S.; as a result, these kinds of systems will only increase the value of English as a second language with special importance in international communications. Many anecdotal reports support this basis for a growing interest in learning English.

6.2.2 Hybrid Analog-Digital Languages

Globalization brings with it (and benefits from) extensive international tourism and business travel. Although a lingua franca can solve many of the communications problems encountered when travelling outside one's own country, there are areas of travel activity for which a fairly small but standard set of signals is far more valuable than any complete oral-textual language. A good example is automobile driving, where certain lights, sounds, and signs have been employed for many years in an effort to achieve greater safety and better traffic control. These systems have gradually been standardized throughout much of the world, with signs warning of everything from speed limits, one-way travel, stopping points, and pedestrian crossings to more esoteric dangers, such as a possible "Reindeer Crossing."[16] When obviously comprehensible analog images (i.e., icons) can be created for warnings, the signs employ them; when that cannot be done, more arbitrary but consistent patterns are used.

Because the uses of solutions that work well tend to be expanded, it is not surprising that road icons have been extended from traffic-control and safety functions to provision of more general travel information. In **Figure 2**, Part A offers an example in the form of signs provided to help tourists on Norwegian highways. When all the standardized traffic control signs are added to those shown in the figure, a fairly significant and near-global icon-based dictionary begins to emerge. Road signs are not the only area of application; packages for shipping expensive or fragile items use another set of icons to help ensure proper handling.

Travel-related signals are an example of a small, new, specialized "language" evolving with the support and cooperation of local governments in response to economic and social needs. The general urge to develop special new words and languages appears widespread—almost a built-in human attribute—and can arise with no active government intervention. Part B of **Figure 2** shows two kinds of language extensions commonly used on computer networks and bulletin boards. Both use standard keyboard inputs and are limited, at present, by the keys available on the boards. The first extension involves the creation of crude, attitude-

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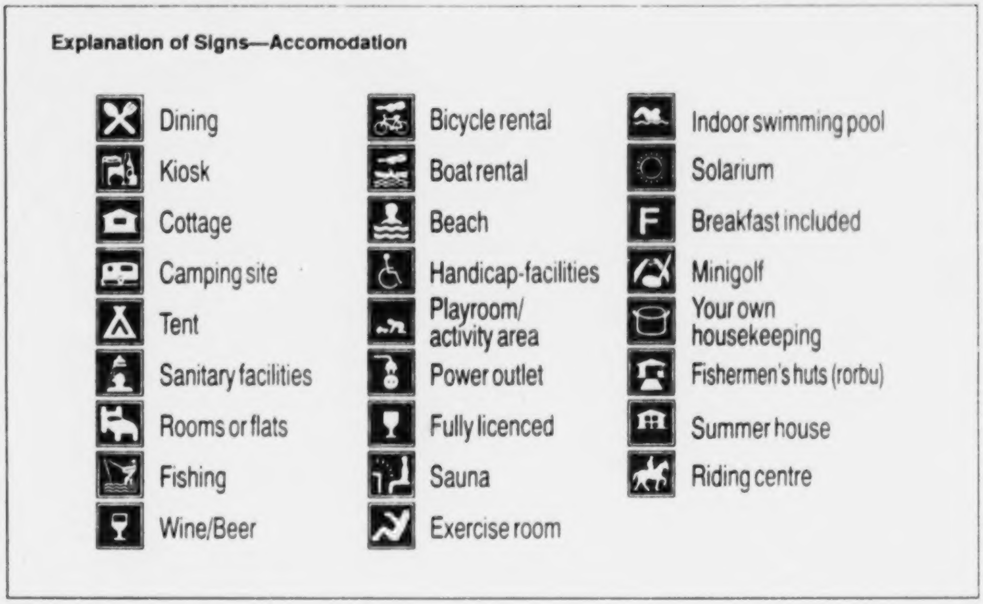
[16] Or "Kangaroo" in Australia or "Alligators" in Florida!

A. Ideographic Extensions in Norway


Explanation of Signs—Accomodation
Dining
Kiosk
Cottage
Camping site
Tent
Sanitary facilities
Rooms or flats
Fishing
Wine/Beer
Bicycle rental
Boat rental
Beach
Handicap-facilities
Playroom/ activity area
Power outlet
Fully licenced
Sauna
Exercise room
Indoor swimming pool
Solarium
F
Breakfast included
Minigolf
Your own housekeeping
Fishermen's huts (rorbu)
Summer house
Riding centre

Source: Norwegian tourist map

B. Networking/Bulletin Board Extensions

Smiley Faces

Smiley faces can be very simple, such as :) or :D . You can add a nose if you like :-) , or glasses **B-)** , or several kinds of hair **#:-)** , **&:-)** , or @:-) . Smiley faces can be wide-eyed **8-)** , winking ;-) , surprised **:-o** , or sticking their tongues out **:-P** and **:-b** . Besides smiling, faces can be sad :-(, very sad (:-(, pouting :-[, smirking :-, , or indifferent :-| . And if all else fails to get your message across, you can send someone a rose: @>-,-'— .

Abbreviations

AAMOF	as a matter of fact	**IWIST**	I wish I'd said that
BTW	by the way	**LOL**	laughing out loud
CU	see you	**OIC**	oh, I see
CUL	see you later	**OTOH**	on the other hand
FWIW	for what it's worth	**POV**	point of view
FYI	for your information	**ROTFL**	rolling on the floor laughing
IC	I see	**RTM**	read the manual
IMHO	in my humble opinion	**RTFM**	read the friendly manual
IMNSHO	in my not so humble opinion	**TTBOMK**	to the best of my knowledge
IOW	in other words	**TTFN**	ta ta for now

Source: "Using Computer Bulletin Boards," John Hedtke, MIS press

Figure 2

Examples of Language Extensions

expressing analog images; the second produces what might be called "etiquette-signalling" abbreviations (which may become elements of a global lingua franca).[17]

In the world of computers, the most obvious and widely used example of the use of analog languages has little to do with globalization, business, or travel; instead, it is a response to the alien and unfriendly character (so far as most people are concerned) of computer application languages. Graphical user interfaces (GUIs) employ many icons, which can include user-designed icons, to offer intuitive, friendly PC interface systems. These have helped convert millions of people into PC users, many going on to learn how to employ at least some textual commands as well. GUIs are, in most cases, private sector, proprietary products; this status has limited standardization of symbol (icon) meanings. However, there is a natural fit between PCs and the use of images, so wider application of analog-based information elements seems inevitable.

Returning to the global scene, the combination of strong interest in systems that are user-friendly across borders and the growing use of international computer networks (as demonstrated by the Internet) make it easy to visualize the worldwide growth of "language extensions" of all types. New images will be added for new purposes, and abbreviation lists will be supplemented by new phrases, in other languages as well as English. A variety of sound symbols may also be added to the simple "beeps" and "waves" now used as signals in PCs. Some additions may be intended for specialized purposes and of primary interest only to fairly narrow groups of users; others may have general utility. Further, the process of growth in the use of symbols will become easier; many clip-art software packages and icons are already available commercially, and at least some of the images probably will make their way into use as language symbols.

The importance of these language extensions lies not in their current status but in what they tell us about human aspiration. Early use of them arose mainly among working engineers. Their interest in finding efficient means to express nuances and attitudes, as supplements to their regular text transmissions, led to their creation of new families of symbols appropriate to a computerized environment. The results are at a primitive stage now, but, in the long run, the new symbols could enhance the value of the base language both locally and worldwide. There is even a sense in which the additions go to the very heart of higher level literacy, by contributing new tools for the practice of rhetoric and composition.

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[17] Use of acronyms, analog symbols, and various kinds of language "extensions" to support specialized professional activities is an old and quite common practice; tables containing some of the more common ones can be found in most full-size dictionaries.

6.3 Person-to-Device Communication

Of all the new languages being created, those that enable people to control computers are both the largest in number and size and the most important to considerations of future skills requirements. Although there are exceptions and overlaps, in general every significant type of computer application requires its own special language, and each different producer of that type of application must use a somewhat different language from those used by competitors. Efforts toward standardization are under way and some progress has been made, but proprietary interests have limited the practical level of standardization. Major software houses have been able to copyright both many "look and feel" features and the specific command terminologies of their programs. As long as competitors have viable versions of the same applications, competition among application-language combinations will inhibit the development of standards.

Other factors also hinder standardization. For example, as particular application packages are improved, incorporate new features and new macro commands, access new peripheral devices, or are associated with new overlay programs, usually new commands will be needed. This requirement is likely to lead to both increases in the size of the languages employed and at least some further divergence among the words used in competing command vocabularies. Even larger impacts will arise from the development of new types of applications, which often require (or benefit from) the use of new commands related to specialized aspects of the substantive knowledge behind the application type. Thus, both the addition of new features to old products and the development of new ones will undercut standardization efforts.

Integrated suites of applications from a single producer can make considerable common use of commands across applications. The limits here are set mainly by the need in each application for specialized words derived from its substantive background. But these suites can also lock users into a particular set of application packages (as, indeed, they are intended to do), thereby limiting their ability to choose the specific application packages they might otherwise prefer.

Narrower in scope but less binding on the users' later choices of software are shells or user interface programs, which are associated with, or integrated into, specific operating systems. User interface programs offer a standard means for performing a variety of frequently used operations and "housekeeping" activities and are available as open standards to any application developers that choose to use them. The Macintosh GUI and Microsoft Windows® in its various version are the prime examples of interface programs.

Although many of the competitive dynamics associated with application languages apply also to interfaces, the market forces act somewhat differently. Most customers (whether organizations or individuals) would like to use only one user interface and operating system, even though they expect to employ a variety of application programs and would like to maintain a freedom of choice among the vendors of the programs. In the PC era, in contrast to the earlier mainframe period, the principle of open-systems hardware (at the component level) was established early. One result was an enormously competitive hardware market, in which success has depended on having software creators eager to program for the particular equipment a hardware producer was building. Economies of scale in the huge applications software markets (for ever more complex programs) have tended, in turn, to force concentration in the operating system- and user-interface markets. The result is a very small number of surviving producers of operating system software, and these producers offer systems with increasingly "look-alike" user interfaces. In other words, the late 1990s trend is toward considerable near-standardization in this area of PC operations.

Chapter Seven

Attributes of New Languages

The new person-device communication languages are a major concern when investigating the future skills requirements people will face. Many attributes of these languages can influence the nature of needed skills and how they can be taught. The new languages use familiar human words, but how similar are they to natural languages in other respects? How do they differ?

These questions are examined below. For convenience, the discussion is presented in terms of a system operating with a traditional, rather than a graphical, user interface. When a GUI is used, icons and motions may substitute for some selections on the command menu or the input typing described below. In the future, voice and pen inputs will probably become widely used alternatives to keyboards and pointing devices, but the principles discussed here should remain applicable.

7.1 Vocabularies

Human-device languages must employ very precise command words. The natural-language definitions of the words may be unclear or ambiguous, and the words or phrases may be context-dependent or have different everyday meanings from those they have as commands. Each device command, however, must be presented cleanly and must have just one meaning (although this meaning can sometimes be changed, in a specific manner, by attaching equally precise modifiers). In all cases, the meaning of the command words can be demonstrated perfectly by internal (and often external) response actions of the computer when the command is given.[1]

This characteristic is so familiar to most computer users that it is now taken for granted. Few stop to consider how unusual it is to find this attribute in any language with uses beyond narrow, professional jargon or nomenclature. Society thrives on ambiguity and the flexibility it provides.[2] There may be reasons to try to make future computer command vocabularies a

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[1] For some kinds of commands, computer responses cannot be known completely in advance; for example, the computer may be instructed to pick a random number and then take one of many possible actions on the basis of the size of the number. Such responses do not affect the general validity of the statement; precision and predictability are very different characteristics.

[2] An illustration of the value people attach to ambiguity and flexibility in languages is that it was an important source of support for the oral tradition, when those favoring oral means of maintaining traditions and social records resisted the intrusion of writing. There are, however, important counter-examples, most of them related to "emergency" vocabularies. The most important among these are military command vocabularies, in which very specific meanings for words are critical to avoid misinterpretations in the confusion and intense activity of battle.

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little less precise, because less precision might contribute to the development of computers with more effective capabilities to do a limited amount of "learning." The current nature of the person-machine relationship, however, sets fairly severe limits on what can be expected in the near future. Meanwhile, the need for commands to be precise so the computer will understand them influences the processes by which they can be taught; in particular, it suggests that computers should be able to play a larger role in the teaching.

7.2 Grammars

Just as every word in a person-device command vocabulary has a very precise meaning, the grammar and syntax each program uses to combine these words in meaningful ways have a very precise structure. For most general-user software, the grammar is provided by layering possible command choices (and related requirements) available to a user and using a menu system (or equivalent) to display the choices available at each level.[3] A command or action taken at one level leads to a menu of options for further specifying or implementing commands at the next level. The pattern is repeated for successive levels until a final "go-ahead" is given to what has become a complete command.

The final grammatical structure is always logical, but not necessarily intuitively. Even though English words are used, the syntax may not correspond to grammatical English syntax. Different programs, even different portions of the same program, can use different command syntaxes to perform similar types of operations. In general, this is not a severe restriction.

Thus, both command vocabularies and command grammars vary from one application to another and from one vendor to another, but they always retain the hallmark of a person-device language: the requirement for total precision in selection and execution.

7.3 Responses

So far, this chapter has focussed on the person-to-device portion of person-device communication, with an emphasis on command languages. The PC, however, is an interactive tool, which implies that it will produce responses to human input. The pattern of application development (see **Chapters Eight** and **Nine**) suggests that, as computing power grows and improved understanding of user needs is gained, the responses may become more sophisticated and creative, supplying users with advice and suggestions when appropriate, rather than just the terse, narrow output characteristic of most software developed prior to the mid-1990s.

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[3] The menu system is an excellent example of a major advance on the simplification side of the complexity dynamic (see Chapter Four). It can provide a relatively intuitive interface and considerable economy of effort relative to the input typing needed previously. GUIs go still further in moving complexity "under-the-hood."

The traditional computer response for programs operating with text or numbers or both is easily described:

- It is presented in textual and numerical form, supplemented by simple acoustic signals (usually "beeps" or "waves") or by some specific visible action (retrieving, processing, etc.) of textual, numerical, or other kinds of materials.

- The substance of the response indicates or demonstrates one of the following:

  - compliance with the input command,

  - presentation of options to complete the command, or

  - inability to comply with the command, sometimes accompanied by a reference to the reason for that or an instruction or option for the next user action.

In addition, the response usually ends with a notice of readiness to receive the next input.

Future computer responses will depend to a considerable extent on the nature of future types of application packages, including the substantive knowledge with which the packages are concerned. Enough already is known concerning current and future computer capabilities to suggest some enhancements in responses that can be anticipated:

- A growing fraction of PCs will probably be fully equipped for multimedia operations. Computer responses to commands may be expected to take advantage of the various modes employed in multimedia substance presentations.
  This possibility suggests that audio (using voice synthesis), imagery (through use not only of icons but also of linkage diagrams, photos, and other graphics), and even video will be available for framing responses. Contributions may also come from hybrid-language extensions, some of which may prove sufficiently acceptable to become useful as response elements.

- More easily accessed, selected "Help" mechanisms may even be used automatically when input errors are detected or problems seem to have arisen. Aiding implementation of this possibility is the trend toward incorporating more and more user operating and technical information in on-line "Help" screens. For some software, this is the only detailed user information provided with an application package; a print manual, if desired, must be ordered and paid for separately.

- Although current Help materials are presented almost entirely as text, the dominance of this mode of presentation need not continue indefinitely. Linkage diagrams and Hypertext can be extremely useful for working through and interpreting difficult sets of instructions, as are map-like diagrams of various types. The more difficult the substance with which an application is concerned, the more valuable sophisticated Help materials are. Simplicity for users can yield competitive advantages for those sufficiently perceptive—as the first Lotus 1-2-3® package with its menu bars and Apple's original Macintosh® GUI both demonstrated. Thus, while current (late 1990s) Help materials are a weak reed to rely on, some optimism for their future may be justified by market factors that can work in their favor.

These possibilities all build on the natural-language-based commands now in use. Image-oriented (and perhaps audio signal) extensions, however, can provide command languages with a kind of "vocabulary" without precedent in the human-machine experience. These additions can and should have great simplifying power and intuitive appeal for users, on a global as well as a local basis. As they come into use, they will enrich and expand person-device communication languages. But the number of icons or sounds that can be used as identifiers is limited by the potential loss of attributes of value with increasing numbers and ranges of application. For example, sorting and differentiation operations often are useful for information storage and analysis. These operations are easily performed using alphanumeric records. In contrast, neither the ease of sorting words or items in alphabetical order, nor the differentiation of clearly different words for different but physically apparently very similar looking or sounding objects, can be duplicated in an equivalently simple and effective manner using image or sound symbols as identifiers. The weakness in performing such manipulations suggests that the benefits of using analog and audio symbols will probably degrade as vocabulary size, subtlety, and ranges of application increase. As usual in the battle against complexity, you win some and you lose some!

7.4 Speech Input to Devices

In view of the ordinary and easy use of speech as a means of communication among people, an obvious topic to consider is the potential role of speech for entering instructions and other materials into devices. Computer speech recognition is already in limited use as a means for controlling computers, and, although cumbersome and often slow, it has performed quite well. Improved and more easily used systems will almost certainly become available in the future. The precision requirements needed for control will force the use of a stilted kind of speech, not the easy fluency typical of ordinary conversation. This suggests that, even with speech input, the present general scheme of use is likely to continue to be the most effective one—meaning that speech will be used mainly to make selections among choices, like menu options. Speech would thereby substitute for use of a cursor or mouse. To go far beyond this would seem likely to require interpretation by the computer of the meaning of received speech (i.e., artificial intelligence), not just recognition of the words being spoken.

Speech can also be used to enter data or to dictate a document. In due course, quite good recognition programs should become available, capable of producing acceptable draft output. But accurate dictation is no mean feat—it is a difficult skill not easily learned. Good secretaries can produce excellent drafts from poor dictation, but that results from their cognitive and interpretive skills, not from any rote recognition abilities. Employing speech input to produce good written drafts will not be easy for most users.

Thus, speech recognition can be useful in many ways but will not be a panacea for any of the current major problems facing computer users.

Part Three

Needs and Applications

Chapter Eight

The Growing Needs

The changes underway in the information environment (described in **Chapter Three**) require people to gain new competencies to cope with the emerging conditions. Some of these future requirements are discussed in **Chapter Four**. This chapter presents a detailed look at the specifics of the situation, to develop a more complete picture of future problems and opportunities. Given that these problems call for new skills of a type traditionally associated with literacy, it is useful to a reexamine some features of this subject and some of the ways they have and have not changed over time.

8.1 Where Things Stood in the Mid-1990s

New applications of digital electro-optics, principally those designed to operate on PCs and their associated (current and future) peripherals, will provide the driving force for a large fraction of the changes that will determine the character of future information activities. In this role, individual computer applications can be regarded as special-purpose tools, designed to help produce a specific type of information output or functional result. Because these applications are subject to growth cycles (see section **4.4**), successful applications will tend to expand over time, increasing the detail of what they can do, and grow in scope, by incorporating subject material closely associated with their own areas of coverage (as Spell Checkers have been moved into Word Processors). Eventual stability (with considerable standardization) is no doubt inevitable, but in the mid-1990s, it had not yet arrived for any major mass market applications.

The mass market applications available by the mid-1990s, especially those concerned with (home and business) work activities, were overwhelmingly devoted to doing more efficiently, more easily, more quickly, and with higher quality, tasks largely performed manually (when the economics permitted them to be performed at all) only a few decades earlier. One result of the rapid growth in PC capabilities was that it became technically practical to meet every requirement for creating, accessing, and communicating near-ideal versions of conventionally formatted information products and services, as these products and services were conceived throughout most of the twentieth century.[1] To be more specific, quite suddenly it became technically possible to receive, or to create and deliver, essentially instantaneously, materials in audio, text, graphics or video form, and to then interact concerning these materials totally independent of the geographical locations and state of mobility of those involved—and all of this at relatively low cost.

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[1] For a detailed discussion of this subject, see Ernst, *Computers and Literacy*.

Major changes have already taken place in the use patterns of applications, in response to improvements in efficiency and the related cost reductions that have been achieved. Facsimile (fax), spreadsheets, business graphics, and automated search techniques all are in common use, in sharp contrast to the situation twenty years ago. There have also been numerous (but, for the most part, not yet commercially successful) experiments with new types of formats.[2] And many advances have been made along the periphery of possibilities, where, as PCs have grown rapidly in performance, new kinds of processing have become feasible. These areas—new formats, new types of processing—are where the potential exists, over time, for the creation of totally new families of applications. But by the mid-1990s, these advance had not occurred; a lot was new, but few mass market products for workaday uses were on the shelves that would make a modern Rip van Winkle, awakening after, say, a twenty-year snooze need much explanation.

Forecasting future developments in the evolution of digital electro-optic information tools is hazardous. Risks can be reduced somewhat by narrowing the scope of forecasting requirements and considering only those types of new products and services that would have to arise were PCs and allied equipment to have significant impact on the daily needs of large numbers of individuals. That is, the products and services must affect the character of what it will mean to be literate in the future. Applying this limitation will narrow the field of investigation; and, within the narrowed field, if technically feasible families of applications that can have suitable impacts can be identified, then possibilities exist that the new technologies may have very broad, direct consequences for the future information and education environments.

8.2 Reviewing the Roles of Literacy

The term, literacy, as noted earlier, is used here in a very broad sense to signify the knowledge and skills for information creation and communications that are important to the future welfare of individuals and nations. To appreciate the role of literacy in current life, it is helpful to review the reasons for which it has been considered important in the past and the purposes and functions that made it so. This subject was touched on in **Chapter Two**; an expanded view is presented here.

Broadly speaking, four related and overlapping reasons have existed for societies' serious interest in literacy:

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[2] This situation may change before the end of the turn of the century. If it does, much credit for the successes may be due to the excellent test bed provided by the Internet and to the large market potential opened up by rapid growth in interactive CD applications.

1. to enable and encourage specific kinds of common participatory activities by the members of these societies,

2. as a major vehicle for conducting broad education processes,

3. as a means for individuals to access and use information resources that can offer personal economic advantage, spiritual growth, and recreational opportunities, and

4. to assure the availability of adequate learning and communications skills at the national level, to support a country's defense and economic goals.

Literacy usually is important not so much as a goal in itself, but more as a means, or process tool, to achieve broader social purposes. Further, with the definition of literacy used here, the four reasons apply, regardless of which specific skills (e.g., oratory, reading, writing, dictating, etc.) are considered requisites, at a given time and place, for being literate. Requisites have changed over time and will continue to change.

Attitudes toward the four purposes, their relative importance, and the form in which they are expressed have varied widely over time and across cultures, as illustrated by the following examples:

- Religious participation, in a form that required ability to read the Bible in English, was of great importance to Protestants in Colonial New England; in the same period, no other major religious group, with the exception of the Jews, had practices that provided equivalent incentives for learning to read.

- Even limited knowledge of the church language (Latin) could be of great value in early Norman England, though more for certain rights it conferred on possessors than for participation in worship. In the fourteenth century, persons accused of a felony who could read a little Latin could claim the "benefits of *clergie*" and thereby escape a penalty of death by hanging.[3]

- Prior to the invention of radio, an ability to read news and speeches was almost a prerequisite, in the United States, for fulfilling the duties of citizenship and participating in politics and voting. This view has encouraged attempts to achieve universal literacy in many democratic nations. In politics, however, literacy can be neutral; as more effective means for controlling information and spreading propaganda were developed, high levels of literacy became a goal for some dictatorships, as a means to increase popular support and loyalty to the party in power.

- Economic forces also have been important. Before the Industrial Revolution, few jobs required the skills that today are associated with literacy; but as that revolution proceeded, the ability to conduct growing numbers of transactions and record them in

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[3] M. T. Clanchy, *From Memory to Written Record* (Cambridge, Mass.: Harvard University Press, 1979), 196, 262). See also Martin L. Ernst, *Computers and Literacy: Redefining Each Other* (Cambridge, Mass.: Harvard University Program on Information Resources Policy, August 1994, P-94-5).

> writing became an important requisite for effective participation in the work force (or in military organizations) of the day. The need for a labor force with at least rudimentary reading and writing skills provided strong incentives in many countries to modernize and improve education systems. The economic basis for encouraging literacy was then broadened, as mass print information products and services began to be produced.[4] These required large audiences for commercial success, so their providers began to encourage universal schooling which would create such audiences.

The value of literacy in the education process has already been noted in **Chapter Two** along with the adage quoted there, "learn to read, then read to learn." To some extent, this may now be inadequate and incomplete, but for many decades it was appropriate. Before the complexities of the twentieth century, much self-education was possible once people learned to read. Even for professions such as law, engineering, or medicine reading supplemented by apprenticeship allowed those who could not afford to attend advanced educational institutions to bypass that barrier and enter their chosen field directly (even if somewhat more slowly than those who could afford formal education). This strong benefit of traditional literacy has weakened steadily since early in the twentieth century, as requirements for many of the most desirable types of employment became more complex and difficult to master without extensive advanced training. In many fields, formal licensing or certification has become a requirement, under conditions that, de facto, force attendance at a recognized certifying institution. A socially important response to the new demands has been a significant increase in the number and size of the sources that provide such advanced education.

Competition with the written word arose also as photographic and electronic techniques offered alternative means for mass communications—first, with pictures, then, movies, telephone, and radio, and, still later, TV. The use in education of more "experiential" means than those provided by reading alone began to be explored. This interest in experiential approaches has continued, with hopes that computer-based "virtual reality" will enable significant advances in the future.

In the mid-1990s, the situation was clouded by the terrible ergonomics of computer-driven displays used for reading. Efforts to build PC programs that combine reading with other computer processes generally have flourished only when the reading component was small or in the form of many brief items (e.g., in e-mail, or in an encyclopedia). Major efforts are going into the development of inexpensive, high-quality, book-size flat-panel displays, which eventually might solve the computer reading ergonomic problem.[5] If such displays become available, computer capabilities that already exist could make future electronic "books" superior to paper books as reading vehicles. The role of computer-driven, educational reading products then could be determined by their inherent capacity to contribute to the learning process, rather than being almost eliminated by the poor ergonomic features of their display systems.

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[4] The steam-powered rotary press was the tool that made mass production of information materials practical, illustrating again the close links between information and technology.

[5] Markets for this type of display could become enormous, because the same type of device is critical to the development of good quality portable television.

For a more general view of the roles of competing mechanisms for education, consider the balance of the two elements needed, in some mix, for all human activities:

- **knowledge**, which amounts to "acquaintance with or understanding of a science, art, or technique," and

- **skills**, which are "a learned power of doing something competently."[6]

Skills are the action component and dominate the requirements for such activities as sports, typing, speaking, and many others. Even here, some knowledge—the cerebral component of the activity—is always needed. Typical knowledge requirements concern the rules of the game, the characteristics of tools and equipment, the strategies available, the required or desired output, the capabilities and anticipated actions of competitors, and many other kinds of background information. On the other side, in many activities knowledge requirements dominate, especially in the education process; but in all these activities, physical skills such as reading and speaking[7] are critical.

Skills always require practice—even the intellectual skills of reading and conversing—and practice is simply a means to gain experience under favorable circumstances. The need for practice suggests that experiential educational tools can be very valuable. Computer applications for some kinds of skill development have already achieved major success, as illustrated by the size of the computer-based video-action-games market![8] There are also many work-related products, of a wide range in size and complexity. At the simple end of the scale, an example is application programs for the PC that help the user to learn how to type skillfully. At the complex end, and employing much larger computer equipment, for many years airlines have used flight simulators to train pilots, and the military Services have a long tradition of using simulation devices for training. Continued progress can be expected in the

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[6] Webster's Dictionary.

[7] Speaking may be primarily a skill, but speaking meaningfully and effectively (i.e., employing the art of rhetoric) requires the careful selection of words and structuring of phrases from an extensive vocabulary as well as considerable knowledge concerning the audience, the subject under discussion, etc.

[8] Video game machines are viewed as a separate sector of the computer industry, even though many games can be played on PCs. For the purposes of this report, all types of smaller workstations, PCs, and the more sophisticated game machines are treated as essentially indistinguishable.

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use of computer-aided systems for training in skills. If (or as) virtual reality eventually becomes widely practical, some of its earliest consumer-level applications will probably be for improving skills, through the use of advanced versions of sports training equipment.

Acquisition of knowledge poses different problems. Although experience is still valuable, all professionals encounter situations for which effective performance requires more knowledge than can possibly be gained from direct personal exposure. In simple terms, they must learn from the experience of others. Computer audio-visual and interactive multimedia techniques have growing roles to play here and may become a major factor in knowledge acquisition in the future. For the present, however, and for at least into the next century, there are strong arguments for reading remaining a critical ingredient of learning when *mastery* of extensive amounts of knowledge is desired. "Reading...is an indispensable [way] when the purpose is to develop a structured understanding, rather than an impression, or an emotional experience, of reality."[9] Given reasonable optimism about the future development of flat-panel reading devices and about an increased acceptance of electronic displays for reading extensive amounts of text that these devices should create, a continuing important role for reading in most knowledge-acquisition processes seems almost certain, even in a largely electronic environment.[10]

The third function of literacy—to support the use of information for personal economic benefit, spiritual development, and recreation—is market-driven. Starting from a weak base in the Middle Ages, when reading anything other than a religious text was suspect in most advanced cultures of the day, supplying information materials for personal economic benefit or recreational purposes has grown into a vast industry. New technologies and media have repeatedly forced structural change or obsolescence on existing media, but few of the older media have disappeared completely. The general pattern is supplementation, rather than replacement. Many of the "Changes" described in **Chapter Three** result from the growth in the quantity and variety of and the general richness incorporated into informational materials now marketed to the general public.

The final function of literacy is to support the establishment and maintenance of national economic and military strength, in line with the political objectives of a country. Until quite recently, the connection between a national level of literacy and a country's competitive position in industry and its potential military strength was at best tenuous. Only in the half-century or so since the Second World War have political leaders come to recognize that, given the fast-paced changes of the current world, both economic and military activities will be most successful if they can rely on the availability of a well-educated population capable of learning needed new skills rapidly. Improvements to the quality of national levels of education and the development of appropriate, up-to-date skills in literacy as part of that education have nowhere to go to but grow in importance.

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[9] Dan Lacy, "The Diverse Psychologies and Functions of Print and Electronics," *Book Review Quarterly* (Spring 1985), 19. Lacy emphasized that writing requires the author to "abstract a number of single bits of the surrounding experience" and "assert a structured relationship among them." The reader benefits from this processing, as well as from the need to "have thought intensively about the message" while reading.

[10] For some potential exceptions to these comments, see section 10.2.

8.3 Where Users Need Help

This section identifies information functions and activities that have two characteristics:

- they are largely the result—directly or indirectly—of applications and operations associated with advances in digital electro-optics, and

- they concern areas of growing user needs, which can be mitigated at least to some extent by a mix of traditional literacy and skills in the use of new technologies.

The needs of interest fall into five general categories. For several, people may operate in (or alternate between) two roles—recipient or creator of information—each with somewhat different requirements:

1. Needs concerned with easing the burdens of *learning how to employ* a number of the more generally useful kinds of computer applications (i.e., the new information "tools")

2. Needs concerned with the *management of quantity of information* and particularly management of the flows of inbound information users must deal with,

3. Needs associated with assuring *quality of information*, which includes
    - substance quality: timeliness, accuracy, validity, source reliability, adequacy of detail, etc.
    - presentation quality: attractiveness of layout and ease of use, suitable tables, figures, images, video, and sound, interaction capabilities (if appropriate), etc.
    - analytical quality: technical appropriateness of the procedures being used, validity of data, completeness, verifiability, etc.

4. Needs related to *participation and groupwork*: interacting, networking, bulletin-boarding, joint authoring, etc.

5. Needs related to *managing properly the personal aspects of the information environment* in which all the above activities take place.

These categories, described in detail below, cover all the problems that ensue from areas noted in **Chapter Three** that directly influence the future information environment; they also incorporate elements of all the roles of literacy (see section **8.2**).

8.3.1 Learning to Employ Applications

For most users who are not professional computer specialists, the largest personal investment of effort required is to learn a number of computer languages—that is, to learn enough about operating systems and selected applications to be able to use a computer with reasonable skill and comfort.[11] The learning problem usually has been compounded by a number of factors, such as the following:

- the need to update skills continually as new program versions are issued with new capabilities which often are important to users,
- the need to keep relearning features that are important but used only occasionally and which, owing to limited use, may be forgotten,
- the need to cope with occasional major system changes arising from technical advances or from product-line changes in response to market factors, and
- the need to do all the above in the face of generally poor documentation and tutorials. There are many reasons for this quality problem, but it is partly inherent. Application providers operate in a field characterized both by rapid and continuing change and by a complicated mix of market segments: professionals familiar with the underlying substantive background as well as "amateurs" lacking such knowledge; experienced computer users and others with only limited prior contact with PCs, etc.

Even without considering the possible (and probably growing) requirement to gain significant substantive background, before tackling related computer control languages, the necessary investment in learning to use computers can be large. As noted in **Chapter Four**, the size of the complete vocabularies of major mass-market applications are comparable to that of basic versions of spoken languages.

In the longer term, certain factors may mitigate problems involved in learning the applications: some de facto standardization of basic command codes; improved integration of the collections of applications incorporated into "suites"; slower rates of change for well-established mass-market products; improved user interfaces; and—most important—the arrival of a new generation of computer users endowed with the abilities to learn and adapt characteristic of those raised with a new technology. But the impact of intergenerational change will be a long time coming, and many other factors work in the opposite direction (e.g., continuing increases in the inherent complexity of applications, continuing explosive growth in the range of types of applications—albeit many of them for what currently are specialized purposes, etc.). An important need remains for greatly improved support of computer applications learning activities.

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[11] For a discussion of User costs and benefits, see Martin L. Ernst, *Users and Personal Computers: Languages and Literacy, Costs and Benefits* (Cambridge, Mass.: Harvard University Program on Information Resources Policy, January 1993, P-93-1). See also sections 4.2 and 4.3.

8.3.2 Management of Information Flows

These days it is common to refer to having an "information overload." Although the validity of the expression may be debatable, many aspects of the problem are real and severe. Everyone depends more and more on information derived from more sources in more locations than at any time in the past. Much of this situation is forced on people by what comes to them in the form of incoming flows of information (some requested, some not); but the need to expand information coverage is valid. Businesses (and, in a somewhat different context, governments) can be blind-sided by more kinds of actions taken by a larger number of competitors, based in more parts of the world than ever in the past. And by unanticipated consequences of more details from more regulations, arising in more areas subject to regulation. And by more new products and processes, emanating from more development laboratories in more countries. As Richard Lanham noted, "In a society based on information, the chief scarce commodity would presumably be information, not goods. But we are drowning in information...the scarcest commodity turns out to be not information but the human attention needed to cope with it."[12]

One way or another, information on subjects considered important will be received or actively acquired and absorbed. The presumed wheat will be separated from the apparent chaff; focus and policies will be developed; decisions will be made. The quality of the use of potentially available information resources can be critical to survival; and making consistent good use is becoming more difficult as the torrent of information increases.

Individuals do not fare much better than institutions. In their working lives, they suffer the risks of loss of employment and a degrading of their skills, from all the changes mentioned earlier in this report. At home, they face "volume flow" problems on a scale not so different from what businesses must deal with. In the field of recreational opportunities, for example, TV guides of all types have become so large and complex that they have surrendered much of their value as search support tools. The worst is yet to come; for

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[12] Richard A. Lanham, *The Electronic Word* (Chicago: University of Chicago Press, 1993), 227. Several observers, including Herbert Simon, made similar comments somewhat earlier. A recent example of the situation can be found in an article in the *Wall Street Journal* (April 8, 1997, B1), which noted that a "study of 972 workers at large companies" indicated they sent and received an average of "about 178 messages" each day!

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example, projects have been proposed that (eventually) might provide up to five hundred channels of video movies from which viewers could choose. Selection will not be easy for viewers without information resources far more effective than those now available.

There are many other examples. Getting the best air-travel arrangements depends on either professional assistance or a good personal search capability. Getting good health care may depend on learning enough about one's problems (by using computer-accessed resources) to be able to ask your doctors the tough questions. More and more, purchases are made from home; again, time and money can be saved if more and better information (including, for example, price comparisons) can be accessed for evaluation. More and more personal records must be established, maintained, and processed for tax purposes, or for possible future insurance claims, or for any of a number of reasons. Finally, simple communication is becoming less simple as the choices (e-mail, fax, cellular phone, among others) increase and as the means for finding the correct "address" of a recipient moves from the near certainty of the old telephone book (or operator) to a maze of less certain mechanisms. The richness of the new offerings is spectacular, but it brings with it the danger of indigestion.

For businesses, government, and individuals in their personal lives alike, the need for "tools" to ease and improve management of the flows of information used for all types of purposes is clearly growing.

8.3.3 Management of the Quality of Information

The problem of managing the quantity of information just described is an idiosyncratic one, in the sense that the object is to manage the flows of information in ways that better meet the personal and business needs and interests of specific individuals. Quality poses a more complicated problem, because, in many situations, it can operate in two often intertwined directions—on receivers and on creators-initiators. In the latter role, the goal is to be effective in communicating information to others which will be useful in meeting *their* needs. It therefore depends on an understanding of both the needs and the comprehension capabilities of potential recipients. In the recipient situation, roles are reversed: one seeks to find desirable information prepared by others and, then, to be able to comprehend it. This process includes coping with *the initiator's* modes of communication and ability to communicate.

Recipients will be most comfortable and skilled in handling information items when the form in which they receive them is familiar. This means that information usually will fare best when initiators employ the "accepted" practices of the subject area of interest when planning the delivery and presentation of a specific type (or piece) of substance. Significant changes in this practice are usually introduced only in incremental steps, with large departures employed infrequently—in special situations or when a shock effect is desired.

The general problems in maintaining quality arise from the combination of three factors:

- a large increase in both the amount of information being made available and the number of sources from which it can be obtained,
- a like increase in the number of choices for creators-initiators, concerning all aspects of developing and distributing information, and
- a parallel growth in the number of individuals who must make such choices.

Thus, more people must make informed decisions (both at work and for home purposes) regarding the sources they will use to obtain the various kinds of information they need, balancing the coverage, timeliness, level of detail, reliability, and accuracy (experienced or reputed) of the different offerings available against their costs. Other people (or the same people in different roles), again in larger numbers, will be making similar balancing decisions regarding which attributes and features to package into their personal and business information messages or into more formal products they are creating or marketing. Here, too, the variety of choices available has been expanding rapidly.

Of particular concern is the quality of the substance itself, and here a key factor is that technology, exemplified by the Internet, has been "democratizing" the production and distribution of information. "Anyone" can open a Web site and become a publisher; the economic barriers are very weak, and no other significant restricting forces appear to be filtering material being published. Under these conditions, assurance of the accuracy of substance is difficult. A great deal of valuable information appears to be available on the Internet, but much of it may be little used until more formal means of quality assurance are developed. Until then, users need help to exploit a resource that can be dangerous if not used with care.

Turning to matters of the presentation of information, the format structure area also faces the problem of an enormous range of choices. The number of possible new ways for creators to present information to recipients has grown almost explosively, with the market potentials and the practical patterns for the use of many of them not yet well understood. This is the case even when some variants of the formats in question (such as, say, forms of Interactive Multimedia and Hypertext) will almost certainly receive widespread application in the future. Progress in this area depends primarily on effective experimentation and on the development of professional-level software and related systems to support economical creation of products in these formats. Consumer versions of professional-level software and systems may follow, especially if hobbies or other uses with popular appeal arise. More modest versions of multiple media systems (for example, noninteractive formats) for ordinary business and personal communications are already available for individual use in offices or at home.

At the level of detailed presentation, where decisions must be made about specific features of a document (such as font and font sizes, tables and other graphics) and about document preparation processes (such as indexing and layout), computer applications have been "deprofessionalizing" traditional creative activities. The best and most important work still requires professional attention, but even professional work is being made more difficult by the increase in alternative format structures and design options available, as well as by a trend toward higher standards and expectations for the final output. At the same time, however, less skilled people are subject to pressure from personal interests, competition, and cost savings (in both business and personal life) to incorporate techniques of advanced presentation in their own information output. These techniques will, in due course, include at least some of those used earlier to create the new formats.

Somewhat similar remarks apply to the quality of analysis. Techniques that require computations or manipulations once viewed as so complex that their application had to be entrusted to experts only now can be carried out (whether appropriate or not!) by people with little or no formal training. Spreadsheet operations, discounted cash-flow calculations, multifactor correlation analyses, and simple simulations are examples. Once again, the PC enables individuals to perform at least some previously professional activities, even when they lack any in-depth training in the subject matter with which they are dealing. As suggested in **Chapter Four**, the evidence to date supports the view that if a new but apparently useful capability for handling information were developed, pressure to use it would not be far behind!

Although the setting is different from that of the "the problem of information flow," the net result in the case of the quality of information is very similar: there is just too much! In this case, too much substance is deliverable from too many sources for one to be comfortable with one's ability to evaluate the relative accuracy and reliability of materials being used. Too much substantive material needs to be learned before one really knows what to try to do with applications that, one hopes, will make output of professional quality "easy" to produce. At least some of these problems are getting worse: increased computer power is enabling an evolution in analytical techniques (see section **10.2**) with which people generally have had little or no experience. For analyzing and interpreting the consequences of information, there are no clear limits on what new techniques may be identified, developed, and what becomes useful in the future so that eventually they must be added to the user's skills.

8.3.4 Participation and Groupwork

The problems in this area differ from those discussed previously in one important respect: many of them should be alleviated or eliminated over time by normal economic and competitive processes already under way. These processes include: de facto standardization of protocols, practices, and interfaces; related development of software to achieve interconnection capabilities in situations where standardization is impractical or undesirable; the provision of increased network capacities and improved host, server, and PC capabilities; the production of improved electronic indexes and directories; and great increases (for all levels of user skills) in the capabilities of search and retrieval systems; security systems for messages and files; systems for participant identification and verification; software for groupwork; and many other similar types of products and services. The general area of groupwork is characterized by intense activity and strong motivation for providers to simplify, improve, and make "user-friendly" all aspects of their products and services.

For effective participation in network-based activities, users will continue to need to acquire an understanding of networking and groupwork practices, knowledge of acronyms or language extensions used on specific networks, and the ability to use specific network-access and operations programs. With growth in technical performance continuing to provide more power for moving complexity "under the hood," these learning requirements seem unlikely to pose major barriers in the long term. What may be more difficult is for people with very diverse skills, interests, objectives, and quite possibly very different potential personal benefits to learn to work well together when linked only (or mostly) by an electronic network. Situations not previously experienced may be encountered; and both new styles of leadership and new systems of rewards may be needed to achieve good performance.

8.3.5 Management of the Information Environment

The personal investment a user must make in managing his or her own information environment depends largely on the amount of external support available. In general, management needs appear small compared with the personal efforts that must be devoted to learning how to use operating and application programs, but they are critical to being able to employ a PC with comfort and confidence. In such areas as Backup and Updating, important but not highly visible problems may grow as individuals and institutions build bigger (and older) archives of valuable, potentially needed records (along with the associated obsolete processing programs needed with which to access and operate them). In the long term, help may be badly needed in these areas.

Three subjects require attention:

- **Personalization** of the general array of resources under the user's control (e.g., the organization of programs and files, means of access to them, and their controllable features and interrelationships);

- **Organization** of all types of data to assure later ability to identify, locate, and access material when desired; and

- **Backup and Updating** of materials and systems, to provide the ability to perform effective "damage control" in the event of accident or a deliberately induced hardware or software failure (for example, from viruses) and to assure access to and use of older resources (especially important archival records) over extended time and through many changes in equipment and software.

The first subject is largely a matter of designing computer software, at both the system and the applications levels, to make it easy for a specific user to select among available management and control options in a way that will best meet personal preferences. Typical requirements placed on the user involve establishing a general "architecture" of programs and utilities, then implementing it through the operating system or by building a variety of small batch programs, menus, and macro instructions to support normal operations. For most users, the second area can be handled by taking two steps: organizing files in a consistent way, with file and directory names clearly related to subject matter, and having a good "search and view" application available,[13] to support access operations when more direct methods of identification fail. Although simple in concept, these solutions grow difficult and complex to apply as personal libraries of programs and data files continue to grow. Both increased software support and stronger personal skills may be needed over time, simply to keep up with growth in requirements.

The last subject in the list is by far the most difficult to deal with, especially Updating, because it seeks to counter some effects of obsolescence in a fast-changing environment. The practical question can be phrased as: how to maintain useful access to old records (such as financial records, lists of names, key dates, household inventories, recipes, or other materials that retain value over time) when the hardware or software, or both, used to build the records becomes obsolete and is replaced? Detailed versions of this question can appear in many forms, depending on aspects such as whether the filed material is used continually (as many name and calendar files are) or is archival (old tax records); whether sufficient storage capacity may be available in new hardware and software to duplicate all old programs and records; whether new equipment and software can update existing old records (a question that comes up because there sometimes is direct incompatibility between old and new equipment or software or because too many intermediate versions of the old software have never been acquired); and other similar matters.

There is no easy, general solution to this problem; it represents the obverse side of a feature of tremendous benefit to users of PCs—rapid technical and economic improvement. For the needs that Backing Up and Updating seek to satisfy, however, the fast pace constitutes a major weakness in electronic information systems relative to printed information. Some assistance for user backup and updating operations should be possible through special software programs. More important, training can help users become aware of potential problems in this area and can help prepare them in advance. Beyond these limited steps, there is little obvious that can be done.

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[13] An early example of this type of application is Lotus's Magellan® program.

8.4 Some Emerging New Information Capabilities

So far, attention here has been focused on problems of information systems of the present and near future and on means to alleviate them. This approach was taken, because, as of the mid-1990s, no computer products or services were available that were both structurally new (in a fundamental sense) and in relatively common (i.e., mass-market) use. What was available were electronic versions of earlier print-on-paper, audio, and video products and extensions, and combinations or modifications of them. Digital electronics brought many new capabilities, enormous operating and economic benefits, and large changes in use patterns to these traditional types of information formats, but one feature was hardly touched: textual materials (including graphics and static images) remained central to most nonentertainment (as well as many entertainment) information activities. Reading and writing retained their position at the heart of literacy and education, even though the PC environment provided myriad ways not previously practical to express reading and writing abilities and to supplement these abilities with elements from other information-presentation modes. But will this continue? Are there no threats to the dominance of the written word in the work and education areas of information processing and transfer?

In the near term—say, the first decade of the next century—the answer appears to be "No," at least so far as mass markets are concerned. But for farther in the future, the answer is less clear; forerunners of possible major new types of applications have appeared which can have important uses in future education, professions, businesses, and, in some cases, entertainment. Some applications may make little use of text—for the simple reason that text is inadequate to describe the information output or, in some instances, even to comment effectively on it.

The most obvious examples of such applications are Virtual Reality (VR) products. Whether for workaday purposes, such as training simulators, or in VR games, text output is never a consideration. The whole purpose is to provide the user's entire mind and body with a replica of a significant physical experience—and the experiences of "reading" and "writing" are not likely ever to be the key subjects of a VR product!

A second family consists of products that permit magnification, rotation, and "slicing" of an image of a solid object being studied, to provide a form of three-dimensional (3-D) viewing of it. A good example of what can be done in this area are the displays of the

"Visible Man" and "Visible Woman" in the National Library of Medicine. These provide a large database of human anatomy, which includes a set of overall human body scans and an enormous collection of body slices (1 mm thick) for sections of the body and for individual organs. This combination provides an enormous amount of anatomical detail, and the material can be shown with the added benefit of the context provided by surrounding body elements. While viewing, the user can control many features of what is displayed and how.

A more active form of 3-D is accompanied by the ability to perform various kinds of manipulations of the image. A good example comes from protein chemistry. The structures of most proteins are extremely difficult to comprehend from linear or two-dimensional presentations; full comprehension of the shape (which can be key to understanding the molecule's properties) requires a way to view a model of the molecule in three dimensions. When a 3-D model is combined with the ability to perform useful simulated activity, such as showing the interaction of the protein model with the model of an existing or postulated enzyme, the value of such viewing is greatly enhanced. This kind of capability makes computers critical to progress in a number of very active fields in science and engineering.

A last example concerns problems that are dynamic in nature and for which no useful analytical solutions can be presented in simple numerical or graphical form. If the dynamics of a particular subject provide the main topic of interest, some form of simulation must be used so that changes can be tracked through a series of events or time intervals. One class of these problems has attracted considerable attention in recent years, an area of nonlinear dynamics often referred to as Complexity Theory.

A number of applications of Complexity Theory have dealt with situations in which, given appropriate input parameters, at least some of the (interacting) items studied exhibit an ability to self-organize and adapt to their environment. Major features in these problems concern the way the dynamics operate and how they are changed as key input parameters are altered. To some extent, as the simulation proceeds, the output can be observed visually as changes in color-coded patterns on map-like displays or in animated, 3-D diagrams of structured output. A variety of nonlinear problems have been studied using these simulation techniques, in mathematics, economics, biology, chemistry, ecology, and genetics.

Most of the examples described in this section involve some form of simulation, although the purposes of the simulations vary widely. In the case of VR, simulation is the main object of the exercise. In the other examples, simulations are used to conduct a *gedanken* ("thought") experiment (in chemistry) and to study and interpret problems investigated using a particular area (Complexity Theory) of nonlinear dynamics. Of special interest, the structures of the simulation models used in most of the nonlinear dynamics application areas mentioned had much in common and were derived from similar or related concepts.

These features suggest that simulations may have a rather special role in future information activities. They provide a tool particularly well matched to the capabilities of computers; and, for some classes of problems, few if any effective alternative methodologies are available. The indication of commonality in underlying structures among the Complexity Theory models offers the possibility that a common set of simulation modules and tools may eventually be developed that might simplify the tasks of building and interpreting specific-purpose versions of these (and related) kinds of simulations. If so, the sets of modules might represent the vocabularies (of "adjustable words") of new and rather different types of high-level "languages," designed to describe (for computers) activities taking place within various virtual situations and environments.

These examples involve only a few of the fields of work (and play) from which future product possibilities can be drawn. Many other types of useful and important applications will probably require (or benefit enormously from having) output presented on computer-driven, interactive, dynamic displays rather than in a static format like text and graphics or a noninteractive format like regular video. Several forces are acting to favor the emergence of these and other types of radically new techniques and products. By the late 1990s, for example, the computer-skilled population will reach what could be a kind of "take-off" point in numbers and abilities. A new generation of college graduates, a significant fraction of them accustomed to using computers since youth, will begin to join the workforce. They will approach tasks with a much higher level of comfort in using PCs (and associated equipment and systems) than their predecessors had and with much greater ability to figure out how PCs may be used to help them in new ways. They will, thus, greatly expand the population of those competent to identify and even implement new ideas for applications.

As already implied, simulation certainly will not be the only example of a new technique arising, with a potential for radical advances as it begins to be used; its current application areas may be only the entry points from which its uses can spread. The second factor encouraging confidence in the growth of new techniques and products is simply that, at the detailed level, the unexplored territory of possible applications is vast. One reason for this view can be seen in **Table 2**, which lists some defining characteristics of the major historical

Table 2

Characteristics of Major Historical Information Formats

Information Format	Presentation		User-storable Information		Interactive	
	Static	Dynamic	Yes	No	Yes	No
Speech		✓		✓	✓	
Fixed Signals	✓			✓		✓
Variable Signals		✓		✓	✓	
Text: Written or Printed	✓		✓			✓
Photographs	✓		✓			✓
Movies		✓		✓		✓
Records, Tapes		✓	✓			✓
Telegraph, Telex	✓		✓			✓
Telephone		✓		✓	✓	
Radio		✓		✓		✓
Television		✓		✓		✓
Television + VCR		✓	✓			✓
Computer-driven Products*	✓	✓	✓		✓	

*"Computer-driven products" are publications devoted to the provision of substance that employ (and take advantage of) the capabilities of a computer to store (briefly or for an extended time), manipulate, and present substance. Examples are CD-ROM encyclopedias, atlases, and other compilations (catalogs, directories), as well as single publications or collected works of individual authors.

information formats. What is noteworthy are the limitations of these older formats that now have been removed. Only three of the older formats (which include natural speech) were *interactive* in nature; only one of them (telephone) operated over *extended distances*; and with none of the interactive formats could the user *easily store and retrieve* the information being processed. In a similar vein, the older formats were devoted exclusively to either a static or a dynamic information display; not until computers arrived was a tool available that was at home with either mode or with a mix of both for presenting information.

Thus, in terms of opportunities to advance and human resources to support an advance, it is hard to visualize being other than still early in the digital electro-optics era. Computers have had a very liberating impact on the uses of historical formats, but, in a sense, until recently they offered only alternative, vastly improved ways to provide these same formats. In contrast, computers are *the tools*—and at present *the only tools*—with which it is practical to study complicated, interactive, dynamic phenomena, especially those that may require new presentation formats that combine static and dynamic output to enable effective and economical interpretation of results. These phenomena could not be studied meaningfully in the past, so most of them received little or no serious attention (and, in many cases, were not even identified or defined in meaningful ways). It is not surprising, therefore, that so few useful applications related to them were developed in the brief fifteen years or so since IBM produced its first PC and opened the path for the "computer-on-every-desk" environment.

The implications for education and literacy of the possible new types of computer applications depend considerably on three questions:

1. Will significant numbers of the new types of products and services gain mass markets that, in total, will cover a variety of kinds of uses (i.e., professional, business, educational, recreational, etc.)? If they do, the nature of literacy almost certainly will undergo changes at all levels, but if their use is concentrated in narrow professional and other work areas, only the higher levels of literacy will be affected directly.

2. How long (if ever) will it be before enough of the new classes of applications are in use so that their presence will make a sizable impact?

3. And, finally, what time will be needed to take effective action on the literacy and education fronts, and what near-term actions, if any, may be sensible to take?

The first item deals with the extent to which the patterns of the use of applications on large numbers of future PCs will have some radical new features or whether they will mostly be "more of the same." The next two questions concern the pace of changes—the pace of "external" changes that computers may enable and then encourage society to adopt, and the pace with which society can recognize and adapt, in appropriate ways, by making changes in institutions. Pace considerations are important, because, although some aspects of education and literacy are essentially timeless, others are not. Some of those not timeless are rather long-term matters involving what amounts to intergenerational periods to effect changes. They often require important learning of a type best done early in life, the full range of results of which are often not evident until much later. Hence, a certain amount of long-term thinking is needed, even in the face of great uncertainties.

Although the uncertainties associated with most aspects of the current information environment are enormous, the general features of the discussion suggest that at least some thinking should be done on the assumption that major changes will arise in one to two decades.

Traditional concepts of literacy can be assumed to have evolved in response to the needs of past information environments. The new literacy will need to deal with the consequences of the availability and characteristics of the new information tools (e.g., PC applications). Of

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particular importance are tools that can help users manage (or exploit) changes to the information environment under way (see section **9.2**) in order to participate more effectively in educational, economic, spiritual, and recreational information activities of the future. A number of these applications of special interest will be devoted to mitigating the negative effects of recent changes in the information environment, even though the applications themselves depend on the same basic technologies (digital electro-optics) as the operations that helped bring about the negative changes.

Using the concept described in section **2.1**, the heart of future literacy becomes a matter of having:

- a traditional literacy background, that is, competence in reading, writing, and simple numeracy, supplemented by

- an understanding of (i.e., knowledge of) and an ability to control and use effectively (i.e., skills for) an appropriate and useful collection of generic PC applications, plus

- a capacity to use this knowledge and these skills as support for learning other new applications, as needed or desired, thereby broadening the potential range of applications covered in the personal collection, accompanied by

- an appreciation of both the capabilities and the limitations of the tools and applications employed and of the personal management requirements that must be met in order to conduct continuing, effective, and safe PC operations (see **Chapters Ten** and **Eleven**).

Provided students can be given opportunities to acquire this knowledge and these skills, the historical pattern of a close, supportive relationship between literacy and education can continue, with benefits to both. In the likely continuing environment of fast change in the next few decades, people will need all the help they can get.

Chapter Nine

Software That Can Make a Difference

9.1 Some Software Categories (as Users Relate to Them)

Chapter Eight identified areas of the future information environment in which people face growing problems and require help if they are to make effective use of resources potentially available to them. This chapter examines the nature of some computer software aids that give promise of providing the needed help. With attention confined to needs that involve the use of computers for relatively serious purposes, whether work-related or recreational, the review of problem areas suggested that the most critical ones concern the following:

- controlling information flows in ways that will improve the ability of users to obtain and concentrate on the materials most important to them, and

- easing the burden and simplifying the process of learning the substantive knowledge and computer-control procedures needed to be effective in a considerable range of user-relevant operating, systems management, and application programs.

If software tools can be developed to help handle these problem areas, and especially if the tools have both features in common (to ease learning to use them) and relatively wide applicability (to make them more valuable to know), then understanding their uses and limitations will be central to future education. The process can be one whereby computer-based capabilities become totally natural additions to the toolkit of literacy.

To set the background for examining computer tools that can help users, a brief review of the main categories of computer software is helpful. Four categories are employed:

1. **Functional applications** are devoted to accomplishing specific information activities, such as preparing a document or finding and retrieving a specific type of (or a specific item of) locally or remotely stored data.

2. **Operating systems** are concerned with personalization and control of internal resources: the hardware, software, and data files directly available to a user; the interactions among them; the basic operator-machine interface; and the establishment of back-up resources and procedures.

3. **Management applications** deal with control of the general external information environment, for aspects where control is practical, such as specification of selected features of incoming flows of information that are relevant to the user's purposes.

4. **"Published Substance products"** which is a term used to describe products designed primarily for the presentation of substance. They do not include action games or any tools for the kinds of purposes that provide the traditional basis for functional applications. Instead, they resemble successors to books and magazines of all kinds and are devoted to presenting general background, reference, education, and entertainment materials. They may make use of several types of media and employ at least some interactive features to achieve their objectives.

The first two categories involve traditional computer operations. The third is an emerging capability that, to date, has had only limited use, primarily in the form of programs designed to find or filter information from specific data sources like news wires. The fourth is represented, in the mid-1990s, by a growing number of CD-ROM products.

The market penetration of major new types of application software has followed a fairly consistent pattern. With the exception of games and other recreational programs, new kinds of software tend to have their initial uses in universities, business, or, sometimes, government. If an application becomes a consumer product, it usually happens only after enough experience has been gained to strengthen the program's reliability, extend its range of capabilities, and simplify its use. Even then, success in the consumer market can be delayed, waiting for progress in hardware to provide equipment with adequate power, at acceptable cost, both to run the program at reasonable speed and to "hide" enough of the inherent complexity of the operation. This penetration pattern is likely to continue, although the early business and government uses of an emerging application may not always be obvious to the casual observer.

As discussed in a previous report,[1] the level of use of a program's capabilities varies widely among users. For a wordprocessing or spreadsheet application, for example, business professionals may use most of the available features at one time or another, while "amateur" (i.e., most home) users may never use more than 5 to 10 percent of the program's capabilities. Since individual users of programs will continue to have very different required (business) or self-selected (personal) levels of skill and interests in using the various features of their programs, this pattern also is likely to continue in the future. For at least some products in the fourth category, however, users may be far more passive, perhaps making use patterns less variable.

The pattern of use for the first two categories (and, potentially, the third) appears to be very similar to the patterns of uses of vocabulary and rhetorical structures in oral and written languages. In this respect, there is at least some correspondence between the recognized existence of multiple levels of traditional literacy and an equivalent set of levels for current computer application "literacy." In both cases, users have strong incentives to gain the capabilities required for success in meeting their personal or business objectives—with efficiency considerations and rapid degradation of unused capabilities limiting the amount of any overqualification that is acquired and retained.

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[1] Ernst, *Users and Personal Computers*, 28.

In the mid-1990s, there is little doubt that software production continues to be a rapidly growing industry. In the area of operating systems, the trend (for reasons discussed in section 6.3) is toward less variety, with only a limited number of different basic systems surviving—and with these increasingly employing a lot of common features in their user interfaces. The area of functional applications, however, is moving in the opposite direction, with increasing variety in offerings as major new software products provide new ways to use computers. Management applications (as defined in the list of the four categories above) are just beginning to be used widely, but they are likely to be needed badly in the future. Published Substance products, in the form of CD-ROMs, are breaking sales records yearly and are well on the way to becoming a major segment of the computer industry (or of the publishing industry, depending on your point of view).

Some products, particularly the Published Substance ones, may place few special learning demands on users; they are more likely to seem enhanced versions of existing products than totally new ones. This characteristic could make them more self-explanatory than most new computer products and inherently simpler to use. In contrast, learning requirements for using and controlling products in the other software categories could require major increases in user time and effort, unless these products are accompanied by new tools designed to ease the learning process.

9.2 New Software for Growing Problems

In the mid-1990s, three lines of development give promise of leading to tools with the kinds of utility that are so badly needed:

1. **Interactive Multimedia (IMM)** based on CD-ROMs; IMM products potentially can provide learning tools with great coverage and effectiveness by employing a mix of media within designs that involve careful combinations of game-like elements and useful substance.

2. **Agents**, a general term for computer programs that can be personalized and then instructed to search for and find the kinds of information desired by the user or, in a more passive role, to filter the user's incoming information flows.

3. **Advisors**, which can assist users in understanding and interpreting both the substantive knowledge behind an application and the language instructions for employing the application effectively in the specific situation facing the user.

IMM, examined in a prior report,[2] is not covered again here. In the mid-1990s, it had already entered a period of rapid market growth, with products primarily devoted to entertainment and reference materials but with growing numbers of specifically educational examples.

The last two types of programs are discussed below. Examples of both types currently exist, but in rather primitive form compared to what clearly is possible.

9.2.1 Agents

The importance of Agents comes from their potential roles in dealing with the problems that arise from the quantity of information available to (or being forced on) users. Agents can operate in two modes: as active "Search Agents," which "go out" and help users find desired information, and, in a more restricted mode, as "Sentry Agents," which help users control flows of inbound communications.

Technically, both types of Agents derive primarily from search programs, which have a long history in computing. Early searches usually were based on entries, in Boolean logic form, of key words that users selected from a list of all the words previously chosen by authors (or librarians) to characterize the individual documents in a collection. Full-text (rather than keyword) Boolean search, and ranking of output references on the basis of statistical analyses of word usage (density, proximity relationships, etc.) in the documents of potential interest followed, as greater computing power increased search capabilities. Until the early 1990s, however, there still were major weaknesses in: dealing with concepts (rather than individual words or phrases); specifying searches that covered all the "near synonyms" an author might have employed in discussing a subject; incorporating context considerations to eliminate the impacts of multiple meanings of word entries; and using word-association data to expand the reach of a search (e.g., by treating the name of a star athlete or a well-known business manager as the equivalent of a synonym or surrogate for the sport or industry involved).

These problems are not yet fully solved, but much progress has been made. In some search systems users can search on synonyms selected from stored dictionaries of synonyms and thesauruses, and sometimes they can construct their own "synonyms" arbitrarily. The latter capability allows users to build limited versions of conceptual and associative networks to define fields of interest. Building these search supports, however, and maintaining and modifying them as either a user's interests, or the characteristics of the original fields of interest change, adds significantly to the effort requirements placed on the user. To reduce user work, much of the necessary support for the most advanced search systems is being done by vendors, who are offering packages that combine search-engine programs and supporting bases of concept and knowledge networks, derived from dictionaries and thesauruses. The support networks are expandable; and, because computer search software is a market with intense competition, the support systems can be expected to grow and improve.

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[2] Ernst, *Computers and Literacy*.

Tho above systems are "direct," in the sense that they help search specific databases that either are immediately available to users, or known by the users and accessible by known means. The full Search Agent concept considers Agents as more active and competent than this, and as having the ability to search afield to find useful databases and the useful data within them. The existing programs that appear closest to operating like Agents of the future have been Internet tools (e.g., Archie, Gopher, Cello, Netfind, and Mosaic), which were designed to help users in such tasks as: establishing contact with relevant database sites for further, more detailed searches; searching widely across the network system for specific files or directory-type information; and browsing among specific materials located by an Agent. Technical extension of these types of tools is certainly practical and, in fact, is being done by a number of vendors.[3] The main barriers to wide use of such tools are more apt to be: user costs for extensive (and often slow) searches on the Internet (especially if the user charge structures become less favorable to individuals than the current charges systems); the need for adequate standardization of database interfaces and search protocols; and the establishment of acceptable licensing and other arrangements for easy access to and use of large numbers of databases (many of which a user may not even know exist).

These paragraphs have concentrated on active search operations, but much of the material applies equally to the Sentry Agent role of filtering. Filtering and prioritizing processes are simply special forms of searching, in which incoming flows of information, rather than libraries or databases, are examined for materials that meet specified criteria for acceptability at a particular level of priority for receiving the user's attention. Systems for filtering have been around for a long time, often operated by vendors of information rather than by users. The most common applications probably have been to newswires, and to similar services supplying fast-changing information. With these systems, items can be explicitly filtered "in" or "out," as well as simply "skipped over." An example of the "out" operation is the capability, already widely used on the Internet, to avoid getting messages from originators or originator groups with whom a user wants no interactions.

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[3] Commercial activity in this area has been increasing rapidly, spurred by opportunities to improve and extend the (mostly originally noncommercial) Internet tools and by the prospects of major markets as the Internet, its member networks, and related commercial service suppliers all grow. In the long run, the most important accomplishment of the Internet may turn out to have been spurring the development of new tools by offering a marvelous (and, to its direct users, an economical) test bed for identifying possibilities and then putting them through real-life trials.

Automatic filtering is obviously critical for incoming-information-flow control, which means that filtering also is key to managing the growing information load (see section **7.2**).

9.2.2 Advisors

The history of search systems that provide the basis for Agent operations goes back to the early days of computers. The basis for creating Advisors also is quite old, but its past performance record is far weaker. The essence of the Advisor concept, in the context of this report, is to incorporate Artificial Intelligence (AI) Expert System techniques into application programs for the following specific purposes:

- to help users understand, appreciate, and use properly the main elements of substantive knowledge underlying a specific application and, similarly,

- to help them to employ the application's command instructions to obtain the types of output they desire.

In providing this assistance, Advisors act to supplement, extend, and expand the roles of the Tutorials and "Help" screens built into much current software.

Concepts for expert systems originated early in the history of AI, and quite a few have been built. A number of them have dealt with "diagnostic" situations, sometimes related to human problems (ranging from analyses of medical symptoms to selecting among financial investment options) and sometimes to equipment (in such areas as maintenance and performance improvement). These types of problems have much in common with some of the difficulties computer users face. While Expert System software has some severe limitations, due to a tendency to be rather rigid in the approaches employed, it can be very helpful for purposes such as:

- applying the substantive knowledge needed to select (and later, in some cases, to confirm) appropriate goals to be sought when using a specific application (such as a particular statistics package) in a given situation;

- choosing the best particular methodology option to use for performing a particular kind of analysis, in cases where several such options are available; and

- obtaining assistance in operations by use of expanded, much more detailed successors to current Help screens.

The diagnostic approach certainly is not the only possible approach for creating a specific kind of Advisor, but it has many nice features for that purpose and illustrates that a significant amount of software development experience can be called on to create and test software for advisory functions.

A proposal to employ AI techniques has to face the rather mixed record of success that has been experienced with AI. Can AI techniques be relied on when building Advisors? For several reasons, it is not unreasonable to answer "yes." First, in spite of weaknesses in many past AI systems, quite a few of the basic techniques employed have been thoroughly integrated into conventional programming and have proved useful.[4] Second, the individual knowledge domains of concern to Advisors can be kept quite limited, and the context normally will be narrow; these restrictions did not apply to many of the earlier AI efforts, which tended to have rather ambitious goals. Further, there should not be much ambiguity to be dealt with, especially in the command-instruction area (because of the precise nature of command vocabularies and grammars noted in sections **7.1** and **7.2**). These factors make the environment for Advisors more favorable than that faced in most of the earlier AI work. Finally, the needs and incentives are strong. A lot of effort has gone into developing Tutorials and Help screens, but few users appear happy with the results. The AI techniques approach has many attributes that seem to match the needs of the situation, as long as ambition and capability are kept in balance.

Agents can have the form of independent software programs, installed and controlled as separate units. Ideally, they are intended to work with multiple databases, provided these conform with particular communications, network, and database software standards and protocols. Advisors are different; they make no sense except when associated with, and in fact built into, other much larger programs (such as particular Application Programs or Operating Systems). A user should seldom have need for more than a few Agents; one or two should meet all his or her needs. Advisors, again, have different requirements; ideally, every program that incorporates multiple options for processing information, in ways best determined by use of complex substantive knowledge, should have its own Advisor. More than one may be desirable if the application has specialized areas that require different, essentially independent sets of knowledge, or if the command instruction process is especially complicated.

As of the mid-1990s, little or no identifiable use has been made of formally titled Advisors that operate in the narrow kind of environment described here, so recognized experience with them is minimal. There have, however, been significant efforts to incorporate "intelligence" (i.e., Advisor-like features) in application Help and Dialog screens.

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[4] The movement of hardware and software technology from AI laboratories to the traditional software developer's "toolbox" has been going on for many years, resulting in a moving and very fuzzy boundary between the two activities. Lots of very simple advisory programs exist in businesses, but they can be hard to recognize and are considered simply part of the local working environment. A growing field for such software is programs designed to help clerical workers, medical technicians and other specialty workers interact better with customers when handling complex telephone inquiries.

If Advisors are to become practical, they will have to be "purpose-driven"; that is, narrow and specific in their goals. They cannot be treated as general purpose learning tools. Advisors, as defined here, must incorporate features not yet well identified, so that they can support their analytical function with appropriate output in the form of indices, linkage diagrams, drawings, and other aids to help specify and work through user problems. However, there is no inherent reason why they cannot be strong contributors to lowering user learning efforts (including the relearning efforts that arise when a seldom used program must be employed). The process of their adoption need not (and probably will not) be dramatic—just steady improvement and extension of existing program support tools, as AI and other useful techniques become integrated into and absorbed by normal software development practices.

9.2.3 Summary

Table 3 summarizes the results of this section; for each General Need (see section **9.1**), particular types of Support Programs are listed separately for Users in their roles as Recipients or as Creators of information. The support mechanisms are by no means the only ones that will be available; for some items, they will not even be the best possible means of support. For example, if available and affordable, formal training usually will be a better means for acquiring Substantive Knowledge than most self-learning approaches using Interactive CD-ROMs. The objectives of the mechanisms noted here are limited, but they should be able to provide individuals with steadily improving forms of assistance for survival in an information environment of continuing rapid change and growing complexity.

9.3 A Crucial Event

Section **8.1** mentioned efforts under way to develop high-quality, book-size (or larger) flat-panel displays for use with both TVs and computers. At this point it becomes important to reiterate how critical flat-panel technology can be.[5] In some respects, the future role of PCs and their part in establishing the nature of future literacy depend on the degree of progress made in this area. Without some suitable form of flat-panel display (or equivalent), computer-driven devices will never be popular for tasks that involve extensive reading. With effective flat panels, the possibilities for improved information transfer of both normal text and mixed media become almost endless.

To amplify these remarks, the current cathode ray tube (CRT) display is very user-unfriendly for extended and concentrated use. The user must adjust position and posture to

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[5] For a more complete discussion of the need for flat-panel reading devices and their potential attributes, see Martin L. Ernst, "Electronic-Print Competition: The Critical Determinants," in Ernst et al., *Mastering the Changing Information World* (Norwood, N.J.: Ablex, 1993), 225-320.

Table 3

Information Management: Categories of Needs and Potential Sources of Support

General Needs	Support Programs (For Users as Recipients)	Support Programs (For Users as Creators)
(i) Learning How to Employ Computer Applications		
• Substantive knowledge	Interactive Multimedia (IMM)	IMM
• Command language	Technique Advisor	Technique Advisor
(ii) Management of Information Flow		
• Inflow/priority control	Sentry Agent	NA*
• Active search/browsing	Search Agent	Search Agent
(iii) Management of Quality of Information		
• Substance quality: Timely, accurate, valid, detailed	Source Advisor	Support Advisor
• Analytical quality: Appropriate analytical techniques	Interpretation Advisor	Technique Advisor
• Presentation quality: Effective presentation	LN**	Technique Advisor
(iv) Participation and Groupwork		
• General operations	Market Forces	Market Forces
• Interactive structure requirements	LN	LN
• Authoring and publishing capabilities	NA	Techhnique Advisor
• Global demographic impacts	LN	Tool Advisors
• Need to use new tools	LN	Tool Advisors
(v) Managing the Information Environment		
• Personalization of resources	NA	LN
• Organization of resources	NA	LN
• Backup and updating or replacement of materials and systems	NA	Little structured help available for Updating or Replacement

* NA = Not Applicable

** LN = Limited Needs

meet the display's (only poorly adjustable) position. This need is in sharp contrast to the operations involved when reading a book or a magazine; these are easily and continuously adaptable to a reader's comfort and convenience. Most CRTs have poor definition compared with a reasonable quality print product. The relatively low definition level is just one of one the factors that limit CRTs to showing far less information on their (typical size) screens than is held by a printed page. The resulting lower information density has disadvantages for many purposes. And all CRTs have at least some "jitter." These difficulties do not cause major problems for most current computer applications, but they are disastrous for others—such as extensive, serious reading.

The difficulties of the CRT are not easily alleviated. In a lecture in London, Alan Kay, a widely respected leader and innovator in computer sciences, described special experiments that involved tracking the detailed eye movements of people while they were reading from CRT displays. The results indicated that subliminal effects of the rapid changes in intensity that are associated with the basic "image-refreshing" process used in CRTs have severe impacts on reading ability and comfort. Kay felt sufficiently strongly on the matter that he noted, "It is almost a crime to put computers into schools to teach reading, because nothing is more antagonistic to the act of reading than a conventional computer screen."[6]

In the long term, flat-panel display technology need not suffer from those problems, but current panels are no match for print (or even the better CRTs) in definition, contrast, viewing angle, or display size. If, however, development programs are successful, dramatic change may ensue.

First, with adequate displays available, computer-driven reading devices (regular computer terminals, handheld mini-PCs, or more specialized reading equipment) could offer a reading environment superior, for most purposes, to that offered by print materials. For example, software already available allows readers to adjust fonts, font sizes, and screen colors, to compensate for vision problems and fatigue, or simply for variety. Readers can also reverse foreground and background to adapt to local light conditions, such as sun or shade. At the reader's option, windows can be inserted to show maps, tables, and other materials referenced in a document, alongside the text where they are discussed. Desired material can be annotated in several simple ways, or spun off easily into personal files. Full text indexing is easy to include, and bookmarks can be inserted and used at will. Finally, although to date the need for computer-driven "browsing" software has been small, many options for skimming materials appear practical.

Browsing brings up a second potential benefit of improved reading displays: they will provide incentives to identify opportunities and then to build reading-support software. Reading support has received little attention in the past, because no significant market was available. Once real market potential is recognized, many avenues can be explored—some mainly to support traditional text materials, others concerned with newer formats, such as Hypertext and versions of Multimedia, for which extensive uses of text turn out to be important.

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[6] The Charles Read Memorial lecture: "PC Screen Text Fails the Test of Readability," *The Financial Times*, May 27, 1994, 1.

Finally, once electronic text becomes more readable, the host of existing library and electronic delivery services can be vastly improved in many obvious ways. Because tangible forms of information products are not needed, having many customers read the same material simultaneously becomes easy. The delivery process can be simplified and made independent of geography, and human portage of any kind becomes unnecessary. An enormous increase in ability to access and acquire information should result.

To summarize, if forms of electronic information that require extensive reading are to become popular in the future, a large improvement in the ease of reading electronic displays is needed. Improved flat panels promise to provide the needed qualities, but considerable research and development are still needed to achieve equipment with suitable combinations of size, performance, ease of use, and price. Without easy readability, electronically displayed materials simply will not be widely accepted in the market whenever extensive reading is needed for their effective use. If the available displays are deemed inadequate, the incentives to experiment and develop new ways to provide reading materials in electronic formats will be weak. Without strong flows of electronic texts, the whole pattern of use of electronic information will be constrained. So, the program to develop flat-panel displays (or an alternative, with equivalent product goals) can be crucial to the character of the information future. Without flat panels, computers will still have an enormous role to fill, but that role would be different from what would be possible with a truly adequate reading display.

Chapter Ten

What Must We Prepare For?

10.1 The Givens

The skills associated with being considered literate in a given society evolve over time, as other cultural features do, by adapting to new circumstances through unplanned trial-and-error processes and deliberate, considered actions. The new circumstances now faced incorporate massive changes underway around the world, affecting all aspects of life. In particular, the new technologies driving the processes of change are altering the skills individuals and nations need and the means of acquiring them. The changes and their impact are the subject of this report, and the items most relevant to the balance of the discussion are summarized below:

- **When preparing for the future, the personal computer[1] should be viewed as here to stay.** Although the various uses of computers may change as time passes, there is no reason to believe their importance will decline and many reasons to expect it will only grow:
    - One factor that will increase the need to have a PC available will be a pattern of steady growth in the quantity and scope of information provided in digital electronic form and thereby made inherently easy and cheap to access. This growth has started, and a feed-back loop will keep it going.
    - The role of the PC will increase and broaden in all aspects of all types of work. In particular, most "well-paid" jobs will increasingly rely on the skilled use of computers; hence, the importance to individuals of entering the work force with a reasonable level of computer competence will grow.
    - The PC will also continue to expand its role in recreation. In this area, simplicity (through "complexity hiding") offers such great commercial benefits to suppliers that they will work hard to keep requirements for user *computer* skills at a minimum for most of their products.
    - Home and personal management uses will multiply and grow in importance and value, especially if and when integrated household systems are developed. Applications in these areas will probably not have the same importance to most people as applications used for work and recreation.

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[1] As a reminder, in Chapter One, the terms PCs and "computer-driven" device were defined as including all digital equipment designed primarily to support individuals in creating, manipulating, storing, and communicating information, regardless of the possible use of other terms when the equipment is physically bundled in a particular way.

- General educational uses of computers have been limited to date, but they have begun to grow more rapidly since better computer-based tools (such as Interactive CD-ROM), easily used communications systems (in the form of E-mail and Fax), and a large number of electronic data sources (available over the Internet) were introduced. There are many reasons (discussed **Chapter Eleven**) for the slow progress to date, but it is becoming critical that educational uses of PCs grow and that computers should become a major educational tool in the mid-range future (see the three items below).

• **Change and growth in computer capabilities will continue to be rapid.** Improvements to and the incorporation of new capabilities into computer hardware and software will continue to be rapid for at least several decades. Radically new types of applications will arise in specialized areas, and at least some of them will diffuse, over time, into more general types of use:

- The new capabilities will create new occupations, make obsolete or downgrade some existing ones, and modify many others in significant ways.

- Mastering the new capabilities will require continuing acquisition of new areas of substantive knowledge; this need arises, in part, because as more kinds of help from computers become widely available, people simply will be expected to know how to "do more kinds of things."

- Similarly, in spite of efforts at "complexity hiding," the spread of new applications (and the growth in scope and detail of existing ones) will act to maintain or increase the required level of computer skills for participation in many important work areas.

• **Continuing education (whether formal or not) and ability to keep learning will become "musts."** Changes resulting from new uses of digital technologies will require adjustments throughout society:

- For most of those seeking economic success and effective social participation, continual adjustment and improvement to information-related skills will be necessary, requiring what amounts to the *deliberate* and *very explicit* continuation of personal education throughout the working lifetime.

- Early experience of education becomes a primary factor in continuing, lifelong education, because it can determine whether one has learned to learn (and learned to enjoy learning to learn). Learning to learn has always been one of the objectives of good education but, too often, has been honored in the breach. Most test procedures are (and frequently must be) oriented toward measuring the specific amounts of substance students have acquired; measuring gains in ability to learn is far more difficult, as is teaching how to learn.

• **As a result of several causes mentioned here, the education problem is growing; and it will continue to grow.** So long as computer capabilities keep growing, the numbers and scope of applications made available will grow, leading to growth in the related requirements for additional education and training. The education requirements will increase even more as applications begin to deal with new subject areas and to appear in new and very different formats:

- Some of the needed knowledge and computer skills will be for working in subject areas not well understood yet, because, until recently, the tools with which to study them (e.g., inexpensive digital processing power and storage capacity; see section **8.4**) were not available.
- Effective computer aids for learning will be critical in this environment; application advisory aids also can be very important.
- Complexity-hiding usually will be very valuable—and sometimes absolutely necessary—but there are limits on how far it can, or should, be employed. For example, complexity-hiding becomes practical only when a computer application or operation is understood well enough for effective mechanisms for simplification to be identified. Rapid expansion in application types is apt to result in self-renewing collections of "leading-edge" computer programs, which can be important to know but have not yet been "simplified." Also, complexity-hiding often operates by selecting and then hiding decisions and options on processing procedures and similar matters; some hidden decisions can critically influence the usefulness, and even the validity, of using a particular application in a particular way.

These items are the givens that must be recognized explicitly in designing actions to improve preparation for the future information environment.

10.2 Attitudes

In most societies, among the features that change very slowly are general attitudes regarding subjects vital to education—attitudes about learning, about the fundamentals to be taught, about the use of languages, the nature of reality and complexity, among others. Well-educated and highly literate people may not agree in their beliefs about such subjects, but they usually agree that these subjects are important and deserve serious attention. One reason computers have had a tremendous impact on society, and are likely to have even greater effect in the future, is that their presence and capabilities tend to force a reexamination, sometimes even redefinition, of many deeply held attitudes about what are held to be important elements of national cultures. This process of reexamination is already under way, and can be expected to continue indefinitely. Some of the broader subjects of concern are reviewed below; other topics are addressed in **Chapter Eleven**, as they are relevant to the material there.

10.2.1 Reality and Validity

The process of blurring the nature of "reality" when communicating information began as soon as speech became descriptive. This is evident in the myths and epics that preceded

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writing. When writing was invented its impact on the use of information was varied and complex. It provided a means to build stable records that reflected, better and more reliably than oral ones could, what had happened and what transactions had taken place. But it also opened up whole new families of means to alter, falsify, distort, and blur all types of records. This, in turn, led to creation of special means for protecting the more important kinds of records against such alterations.

The continuous battle between new ways to blur and new countermeasures to protect expanded with the introduction of more sophisticated devices for the production and delivery of information (e.g., the telegraph, photographs, phonographs, movies, radio, and TV). Throughout these changes, most people felt "in control" of the situation; they believed that, for the information important to them, they could distinguish adequately between close and less close versions of reality and that they knew which information products and instruments could and could not be trusted for a given purpose.

More recently, computer-driven systems began to provide a growing stream of means to create or alter selectively (for both good and bad purposes) the substance carried in essentially all kinds of information formats. By the mid-1990s, PC software for home "improvement" of both audio and image-information was readily available, as were very elementary versions of Virtual Reality games.

The general blurring process is illustrated in **Table 4**,[2] for an extremely simple and (by current standards) unsophisticated example. Starting with physical presence at a concert, the first new versions of the musical output employ traditional methods to change the time, location, and delivery mechanism used from those of the original version. Thereafter, and especially as digital techniques begin to be used, the basic substance undergoes successively greater modification until it can no longer be related to the original version. It is tempting to settle for the attitude that "reality" is moving—that reality for each new version of the concert is a prior version on which the current one is based. This view, however, loses sight of the steps that took place before the directly prior one, thereby sacrificing the full path for the sake of a single (perhaps short-lived) "signpost."

As with other computer advances, there is no clear limit to what can be done. New hardware and software will improve ability to alter the substance of audio and images (both still and video) and ease the process of alteration. It also is likely to make alterations harder to detect. As consumer products, the alteration programs can support hobbies of many kinds; and in business, a wide range of useful applications has already been identified. In both cases, improved means for the detection of "unannounced" changes (that is, built-in validation and

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[2] Many examples of the same sort of phenomena can be found in Gary Gumpert, *Talking Tombstones and Other Tales of the Media Age* (N.Y.: Oxford University Press, 1987).

Table 4

Sequence of Changing Realities

Version of Event	Basis
Original concert	Seen and heard in person
Original concert, remote	Seen and heard on live television
With short delay	Concert taped but not altered; broadcast hours after event for convenience of audience in later time zone
With long delay	Concert taped but not altered; broadcast months after event, for convenience of producer, to fill gap in programming schedule
Edited tape version	Concert tape edited and "improved" with splices from other recordings of same piece by same orchestra; then marketed
Modified tape version	Edited tape further "improved" by digital reconstruction of notes and passages where "errors" occurred
Improved CD version	Digital filtering used to eliminate audience sounds and other noise (applause, disturbances, e.g., coughs) and output transferred to CD
Alternative CD version	Special digital techniques used to convert CD of concert into "novelty" version CD with a different musical structure and different sound effects

verification checks) will become increasingly important. Although the example in **Table 4** is benign, better technologies are becoming easily available and illicit uses are bound to increase.

Particularly with Virtual Reality, a key part of the blurring is the sense that a reliable "real" reality is fading away. Every "reality" experienced is internally real, but the significance of an internal reality—that is, the ability to use the substance of that "reality" to affect someone or something in the external world—can become unknowable to the experiencer and may very well not exist. In ultimate VR, signals would bypass the perceptual organs and be fed directly into the user's nervous system and would no longer act as information-laden symbols of anything "out there." They would only be signals that follow a provider's programming instructions.

Although the possibilities of VR threaten historical attitudes toward "reality," its positive side should not be forgotten. VR can be far more than entertainment; as noted in section **8.4**, in the discussion of simulators, it already is a valuable tool for some kinds of training. Its potential as a broad-based education tool has yet to be carefully examined; a very important role there is entirely possible.

How far back into what used to be trusted formats—accepted as reliable for providing reasonable representations of outside objects and events—will the blurring of inside/outside relationships penetrate? Do technical means exist that can clarify particular types of situations? Will people encounter problems they can handle only if in advance they receive special training? What kind of training? What significant cultural changes, if any, might flow from greater and more widespread ability to blur reality?

10.2.2 Absorption of Information

Once information is created, it must be transferred to become useful. Information transfers require the presentation of structured sets of output symbols (or tokens) to a person (even oneself) or a device in a form that enables the recipient (person or machine) to absorb the substance the symbols represent. For communication to people, the main presentation formats have supported speech, music, writing, graphics, and various types of static and dynamic imagery. Each kind of presentation has its own problems in creation and its own strengths and weaknesses for transferring information for a given purpose. Individual preferences (sometimes reaching levels that might justify using the word "love" rather than "preference") play a major role here, and attitudes toward particular presentation formats, once set, are not easily changed.

The impact of computers on how information can be presented in formats that assist absorption is, for the most part, still in its infancy, but it already includes the following:

- making available great capabilities for experimenting with and developing new ways and formats both to present and enjoy information;
- providing means for distributing and storing massive amounts of information at very low costs;
- enhancing the ability of user-creators to produce materials in all the standard output formats, by providing a variety of tools that simplify the general processes and improve the appearance and quality of the final information presentation;
- enabling the use of new formats which permit (or even require) active interaction by user-recipients;
- combining presentation formats at will, in efforts to create products with the desired overall effects, clarity of intent, artistry, and other features of value; and

- making technically possible or economically practical, or both, a variety of graphic and image techniques that previously rarely, if ever, could be employed in products or output presentations.

All these new capabilities were mentioned earlier in this report, and some of their consequences described. At this point, it is useful to return briefly to one particular set of consequences: the way user skill requirements are multiplying, especially at the high end of the literacy scale. Abilities in composition and rhetoric and sometimes an understanding of a specialized professional vocabulary comprised adequate communication skills in most circumstances prior to the advent of computers. Those skills are now being increased by requirements for at least some (and, for some people, more than a few) new areas of substantive knowledge and computer language skills. In order to comprehend fully the output of some potential new analytical tools, key users may need to improve the range of personal interpretive skills, even if these users themselves seldom touch a keyboard.

To be specific, the need for new interpretive skills can arise because of certain new dynamic analyses (see section **8.4**), the results of which cannot be fully shown except by dynamic displays. Simple charts and graphs now commonly employed to transfer information were relatively scarce as little as fifty years ago. Only a little honing of user analytical skills was needed to learn how to understand such graphic aids. But the use of complex graphs, 3-D linkage diagrams, color-coded matrices and maps, and volumetric slice images—all subject to magnification and rotation (if appropriate) and to dynamic presentation to indicate the results of changes in selected parameters—are a different matter. These offer an entirely new way to visualize intricate information, particularly information about complicated, dynamic phenomena. Although it may prove easy to acquire the needed interpretive skills, that ease cannot be taken for granted, especially if relatively nonintuitive display coding becomes necessary to handle some types of problems.

10.2.3 Languages and Complexity

Languages are definers of cultures and, to a lesser extent, of nations. Given these roles, attitudes toward them are, not surprisingly, strongly held and usually conservative. When global languages arise, they are used as a convenience, or to conform to some set of standard practices or under imperial regimes to identify with the dominant group. In none of these situations would users have the emotional loyalty to the global language given to a native tongue. What loyalty is given to global languages derives almost entirely from practical considerations. Attitudes toward computer languages and the emerging hybrid digital-analog languages (see section **6.2**) mirror those held toward the family of global languages.

Before computers, basic literacy consisted of the ability to read, write, and handle simple manipulations of numbers. Higher literacy involved the use of larger vocabularies (often spoken with a distinctive accent) employed with greater skill. Higher literacy (especially outside the United States) was also ordinarily associated with knowledge of one or more foreign languages. For some, the training in foreign languages was undertaken as a means to increase appreciation of the literature written in these languages and the cultures that literature represented. For others, the purpose was more practical: the languages were needed for engaging in travel, commerce, or a particular profession. But for all the people involved, training was encouraged partly on the basis that in-depth knowledge of a second (or more) language(s) would improve the understanding and skills used in one's own. In the western world, this argument specifically attributed great benefit to skills gained from the so-called dead languages, Latin and Classical Greek, as well as from learning living ones. In general, learning languages was considered a "good thing" to do.[3]

With computer languages, the situation is quite different. Originally, these were regarded as "very technical" and, until the advent of the PC, they were not considered very useful except for specialized purposes. With the growth in the use of computers and PCs, the range of "language" skills required to use a computer well has broadened enormously, with specific needs depending on the particular applications used and their levels of complexity-hiding. At one end in requirements are the simple action games played on consumer electronic devices. These require skillful, rapid physical motions but only minimal specific language requirements. At the other end are very advanced technical and professional applications, requiring not only expert knowledge of both the underlying subject material and the computer command language employed but also often considerable ability to modify and adapt the application program to specific situations of interest. This end of the scale obviously remains "very technical."

Between these extremes lie the applications of greatest interest to this report:

- those sufficiently large, and with enough functional utility, that business or consumer markets have been identified with adequate size, value, and growth potential worth competing for, through product development, extension, and improvement;
- those with sufficient maturity that competition has already forced expansion of the detail and coverage of the application subject area, until a large, complex set of commands is needed to use the application fully; and

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[3] It is worth noting in passing that the full set of requirements for traditional higher literacy inherently incorporated the ability to deal successfully with considerable complexity in the conduct of communications, and that ability is one source of the respect traditionally accorded those recognized as having a high level of literacy

- those with enough complexity-hiding that, for most routine purposes, a relatively small number of commands is adequate, and these commands are accessible through a friendly, intuitive interface.

The above requirements were selected so that applications that would meet them would include most or all PC products with direct impact on many people. That is, they would cover most or all mass market products intended for workaday purposes (including personal activities like hobbies) and those serving large niche markets and important business, professional, and personal functions.

Application languages share some attributes of natural languages. Clearly, they both require a range of levels of literacy in their use, depending on vocabulary and syntax skills, but their differences are more significant: in the loyalty attitudes noted above; in the extent of specialization of uses; and in the rigidity of vocabulary meanings and required syntax (also noted in **Chapter Seven**).

Both computer languages and their users are evolving, and far more quickly than natural languages are able to evolve. The process by which computer languages evolved is through clever uses of layering and complexity-hiding. The earliest computers needed but a single layer of instructions; now there can be many. The bottom layer employs a language designed solely to give the computer detailed, step-by-step instructions. The middle layers are written in languages easier for programmers to use, because they were created for ease of use. The programmer's job is to assure that the output of the middle level programs is acceptable as input to the bottom level, where it is automatically translated into the language the computer "understands." The top layer is the application language; it receives instructions in ways that can be described to users in relatively simple, natural language. These instructions, when used, are converted to the middle level programming language. This maze of languages and programs offers opportunities to reduce the complexity of the application, *as perceived by the user*, by hiding much of it internally—at the cost of greater internal and design complexity.

Future evolution can continue along much the same layering path. A possible goal, one that already has received attention from the National Institute of Standards and Technology (NIST),[4] involves inserting a new kind of layer at the top of the programming languages. The concept is to produce standard interchangeable software "components" that can give software applications the flexibility and simplicity of assembly that hardware now enjoys. This target is a logical continuation of past advances.

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[4] As reported in "Software—Stitch Ups," *The Economist* (Oct. 29, 1994), 99.

Java® (of Sun Microsystems) is a new programming language. Originally, it excited considerable interest because of its plans for a unique delivery and use environment. It was based on application modules residing on the Internet, for access by users "as needed." This meant that the Java language inherently had something in common with the NIST concept: both strongly relied on program modules. Because Java is now operational, it can contribute valuable experience concerning the problems and benefits of the modular approach. At its most successful, its results might revolutionize software production, making it more practical for individual users to build their own applications or modify existing products into personal, specialized programs. The dream is eventually to build a top-level language that would be so natural to use it could be used creatively by those with only limited special training.[5]

Whether this vision can be made reality of course remains uncertain. Because the approach largely continues past trends (although, in this case, the step forward is a big one), at least some progress can be expected. To the extent it occurs, the interchangeability requirements will force a degree of standardization of components not yet seen in applications software. If the results are also widely useful, especially to support new kinds of applications, this approach will provide the basis for a new kind of global language that can accept components from any and all sources, provided these meet the appropriate interface standards and are well documented. The worldwide production of tools to help conduct early operations on the Internet offers a model of what may be forthcoming. The eventual result may be the first computer language that has the kind of use that justifies including skills in its use among the requirements for moderate, or even basic, literacy.

Although many "ifs" are buried in this discussion, at least a thread of a path exists whereby some computer language may approach the status of a natural language.

10.2.4 Work Practices and Skills

The introduction of new information tools, especially those that enable the development of new formats, is often accompanied by changes in the work practices and related general skill requirements most valuable to individuals and institutions. Many of these kinds of changes in recent years have been related to specific computer applications, their command languages, and associated substantive knowledge. Although examples are included throughout earlier sections of this report, the impact of the new tools can be much broader than specific examples suggest. To illustrate:

- During the first half of the twentieth century, information workers either submitted handwritten input (often for later transcription by typists) or dictated input to a secretary

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[5] The simulation "modules" discussed in section 10.2 represented special-purpose and more limited versions of the kinds of components that are the goal of the effort described here.

(if they were in upper-middle-management positions or higher). Secretarial and clerical costs were low; neat writing and skilled dictation were valuable career assets; and typing skills were irrelevant except to clerical typists and secretaries.

- In the second half of this century, typing became the primary means for recording information and, increasingly, involved the use of computers. Typing became a critical skill for a tremendous number of jobs. Secretaries and clerks became relatively more expensive (and less available to assist and support most individual information workers); neatness in handwriting is now a lost art in the west; and the importance of dictation skills has been reduced (and usually employed now by dictating to a tape, rather than a person).

- By early in the twenty-first century, high-quality, low-cost speech recognition software will probably finally become available. Typing ability will matter less; dictation will be back in business! And people will need to relearn how difficult it is to dictate cleanly and without error—and how valuable the "old fashioned" (no longer widely available) professional secretary was, as a quiet corrector of dictation mistakes!

Tremendous changes of this type can be seen throughout recent history. At the start of the twentieth century, national political campaigns were fought out in the newspapers. Franklin Roosevelt's use of radio helped make radio the dominant format. John F. Kennedy's campaign established TV as the top medium, and now, politicians must cultivate considerable acting skills to survive. The high costs of political TV advertising have had profound effects both on campaign financing and on tenor: in a thirty-second time "sound-byte" slot, it's much easier to get across a negative point about an opponent than a positive one about or oneself!

This is only the start of what may be a very long list of changes owing their origin to the new information tools. In many activities, the spoken word is staging a comeback, increasing the importance of the skills of classical rhetoric. Many other changes are arising in industry attitudes toward information and its uses. Business decisions more and more are made by employing a growing number of analytical techniques, to support or to replace earlier judgment calls. Operations of many types are increasingly controlled by procedures that involve manipulations of massive databases. Computer-mediated groupwork is reducing requirements for centralization of the human resources of organizations, as well as for some of what used to be ordinary business travel. Businesses are placing higher value on internal knowledge resources—their stocks of information and personnel skills—and they are exploiting these resources in more ways.

10.2.5 Why Reexaminations Are Needed

The pattern of evolution that characterizes the information environment in recent years reemphasizes the need for continuing education and for learning how to learn. But undertaking to learn and practice skills that are not yet particularly useful (say, how to dictate well) is difficult and involves current risks, even if a future need for them is anticipated. The priority of the effort will be low, and realistic vehicles for training may be hard to find. Even worse, training in new skills will become almost impossible if the skills cannot yet be well defined. Given the great uncertainty about the future information environment, the search for effectiveness and flexibility has become critical in educational processes. An important step in support of these attributes is a careful reexamination of *attitudes* about what is and what is not *needed* to face the more likely future information environments, and what is and is not *important* for effective survival in those environments.

As part of this reexamination, it will be necessary to look below the surface of attitudes, to understand characteristics on which they are based. For example, one attitude mentioned earlier on several occasions is that print-on-paper is a favored means to gain serious knowledge of a subject; this attitude is based on characteristics of print-on-paper, such as the following:

- stability of the format;
- total user control—the format is passive and doesn't drive the user in any way;
- excellent convenience and portability and requires no external power;
- excellent ergonomics and comfort in use; and
- user ability to move freely within the material, to focus and refocus on selected sections, to control timing and order of use, to annotate the material easily while working, to emphasize particular items as desired, and to relate separated elements of information within or among documents.

As indicated in the discussion of flat-panel displays (section **9.3**), for a competitor to print-on-paper seeking to become the primary format for knowledge acquisition to be successful, it must have similar (or equivalent) capabilities *or offer alternative benefits* that outweigh its deficiencies.

The reexamination described above is very narrow and used only as an illustration. The next chapter includes a broader look at the process.

Part Four

A Framework for Action

Chapter Eleven

Pulling the Pieces Together

The previous chapters described the many changes underway in the information environment, including the dynamics driving the process of change and the main consequences—favorable and unfavorable—the changes are having on individuals, businesses, government, and society in general. This final chapter turns attention toward possible actions to benefit from or, at least, better cope with the major effects individuals and organizations are feeling. To set the stage for this discussion, the chapter reviews again the current environment and the problems it is raising, this time in the context of possible steps toward action.

11.1 The Starting Point

11.1.1 What Users See

In the work environment, more and more people's jobs involve significant use of PCs or other types of personally dedicated terminals. A growing fraction of these jobs have become more complicated over time in a variety of ways, leaving job holders increasingly in a position of having:

- too much to learn, too many new skills to acquire, too little time for learning, while everything continues to change and grow and will keep on doing so; and

- too much information of too many kinds from too many sources to deal with—that is, to become aware of; to find or receive (whether requested or forced on one); to absorb, interpret, and analyze; and to discard, forward, save, or use for work, personal affairs, or entertainment.

Some of this overload may be a temporary reaction as people work through the widespread introduction of whole families of new technologies, but continuing changes are certainly expected and in some areas matters seem nearly on the brink of going out of control.

The "too much" syndrome is accompanied by a continuing struggle by software developers to achieve new and greater capabilities without significant increases in the perceived complexity of their products. In the struggle, achieving the goal will be difficult for the leading edge of computer applications, because hiding complexity well takes considerable experience with a subject. Even if reasonable simplicity results, there remains the substantive knowledge to be acquired for proper use of a new type of application. And there also remains that flood of information; communicating masses of information has become so cheap and easy that being flooded by it should cause no surprise!

Since the above are consequences of exploiting major advances in information technology, equivalent effects have probably occurred before, during earlier changes in how information is processed. But the pace and scale of the changes now faced are almost certainly unique: what previously might have been intergenerational adjustments must now be made within a few years. This factor affects both computer users and bystanders.

This situation can be ignored, but at a price that will only increase over time; the young, in particular, will be the most affected by inattention. More important, neglect makes no sense; the same changes responsible for today's problems are bringing enormous benefits—enough to create global economic incentives that will reinforce current trends for at least several decades. To deal with the situation, then, new skills for working with new tools will be needed throughout society. At present, only inadequate means are available to handle these skill requirements effectively:

- No one can afford to add time to the (already long) process of formal education, before people at the high end of the literacy scale (such as doctors, engineers, lawyers, educators, etc.) are ready to start supporting themselves and contributing to the economy. Savings of time must be found elsewhere in the curricula, to balance efforts to be devoted to developing computer and computer applications-related knowledge and skills.

- It is highly unlikely that any "one-time" education process can be counted on to retain value long enough to provide the employment and social participation skills needed by people over their full lifetimes, regardless of where they fit on the "literacy scale."

- A simplistic approach to dealing with these problems will almost certainly involve significant increases in the cost of education, which probably cannot (or will not) be acceptable. Finding a way to balance needed cost increases with reductions elsewhere in the system will be very important.

- These difficulties are compounded by the problem that no one does, or can, know in more than a general way where the environmental changes are headed. The point of concern must be the process, rather than a "Plan," because neither a stable situation nor a stable set of trends exists to serve as a basis for the Plan. Although many factors involved in the process can be influenced, a great deal of flexibility must be retained in order to deal with situations that cannot be anticipated.

11.1.2 Social Concerns

To help determine the kinds of steps likely to be of value, the relevant broad social issues raised by the evolving information environment are reviewed in brief:

- Owing to growth in possible new skills at the high end of the scale, the range of possible levels of literacy within a given population is broadening. The observable result is an increase in the separation between top and bottom levels of literacy. An individual's position on this spectrum largely depends on age and economic status, with the young and wealthy in far better positions than the older and poorer. At least some of this expansion is inherent in the large-scale introduction of new technologies and will probably continue for several decades or more.

- The spread in the range of literacy levels just described will almost certainly load still more problems on those segments of the population already facing severe educational and social difficulties:
  - But schools can do only so much. Even if they were very well equipped, with PCs, software, and means to access on-line services, nothing in sight would help financially poorer students balance the advantages of having PCs available at home, as is already the case for many middle- and upper-class families.
  - Overall, there seems no quick and obvious way to parallel the benefits offered throughout much of this century from the easy availability of libraries. These institutions, at no direct cost to users, could support the spread of traditional literacy and its use by individuals (either at home or in the library) for self-improvement outside (or as a supplement to) the formal education system. It did, however, take a century or so of major public and private investment to create the current library network of the United States. Many libraries, public and private, already employ computers to support their operations in very effective but limited ways. To obtain benefits in the new environment equivalent to the range of those available through the traditional system may require considerable time and resources.

- Although the underlying goals of education will probably remain for the most part unchanged, traditional education curricula and practices face at least partial obsolescence:
  - Some previously important subject areas will need much less attention (or even none) in the future (e.g., spelling and the mechanics of arithmetic). Other areas, many new to most current educators, may require much more effort. But curricula are always being revised. For example, few public high schools still offer courses in Latin, which was a fairly common offering sixty years ago, and the content of math courses has undergone many changes in the same period.
  - Stability in the value of the initial teacher training, traditionally used to develop competence as educators, will decrease. Teachers, more than most members of society, will require continuing education to do their jobs well, and much of it will be in subjects for which many of them already in the education system are not well prepared.

- The new literacy tools will increase opportunities for participation in all information-related social and economic activities by all parts of society. This change will have both positive and negative effects. For example:
  - In politics, the capabilities can encourage greater citizen involvement than has been seen since the days of the Greek city states. The results, however, may

include the same kind of volatile "instant democracy" actions (and, probably, some of the same occasional self-destructiveness) that characterized those states.

- In the not too distant future, the formal education system will almost certainly benefit in many ways from more extensive use of computers. Doing so effectively will probably require many changes, some possibly quite difficult for current participants in the system. The prospects for effective home-based, self-education can be greatly enhanced, but this area is subject to the economic constraints mentioned here.
- In businesses, including personal business, the communications, participative, record-keeping, and analytical benefits of PCs are already well established. One danger here might be too much operation "by the numbers," and too much use of inadequately understood analytical techniques. Such practices might lead to a more sterile, technocratic business environment, to occasional major (avoidable) mistakes, and to neglect of the value and importance of "street smarts."
- In entertainment, the richness of offerings is already multiplying in number, variety, presentation formats, technical quality, and opportunities for interactive user participation. This richness can overwhelm recipient-users, perhaps discouraging participation in matters of more enduring, more important, long-term value. This comment is a variation on clichés used in earlier periods to arouse concern about major changes in popular information technologies. Fortunately, the attitude it embodies is paralleled by the growing ability to counter "couch potato" and "game addiction" syndromes by creating much improved thought-provoking and education-supporting software programs in a variety of formats designed to provide strong motivations for use.

• Advances in technology will continue past trends (although perhaps more weakly) of rapidly decreasing costs for given hardware and software capabilities, even as better understanding of potential new kinds of applications will enable the development of new, more complicated computer uses. Whether the socially negative aspects of the current situation will become exacerbated or alleviated by these changes remains uncertain, but lower costs should ease at least some types of problems.

• Meanwhile, the use of computers as general-purpose tools for creating, distributing, processing, and using information is still in transition. These uses are:

- well-established, widely used, and a required part of almost all business establishments;
- becoming popular in homes for a mix of practical purposes and recreation but on a "voluntary" basis, with firm needs for them being rare; and
- present in growing numbers at most schools but seldom explicitly integrated into the curricula or treated as a potential key factor in the future education process.
- In all these cases, the trend is toward more and more varied use of PCs, but with different growth rates in different sectors and applications areas.

- In this situation, individuals are often left responsible for much of their own learning relationships with PCs:
  - lots of schooling in computers is available—but only if you, your parents, your school district, or your business or employer can afford it and believes in it;
  - advanced education increasingly requires computer skills; but
  - PCs still have a long way to go to become a standard day-to-day tool for processing and communicating information, in a way equivalent to how older, more traditional tools are treated.

11.1.3 When a New Technology Takes Over

When successful new product or service technologies are introduced, they usually grow as "add-ons" to the existing system until they reach a level of 60-70 percent penetration of their natural markets. At this point, a major social or industrial restructuring usually occurs. Sometimes the older industry is made obsolete; when 60 percent or so of the homes in a neighborhood had refrigerators, the iceman could no longer afford to come! In other cases, a change occurred in roles; radio did not make newspapers obsolete, but it took over as a faster deliverer of news and thereby forced the papers to eliminate most "Extra" editions and refocus their contents. There are many such examples, and often important side effects. For example, the success of the automobile led to a huge cutback in public transportation. Those who did not own cars or did not drive were as a result restricted in the residential areas practical for them to live in.

Similarly, few people in business can afford to be without credit cards, even if they were to prefer not to have them; it is hard (even perhaps impossible) to rent a car on a business trip without one. The current credit card situation can be viewed as an example of a form of "computer-driven restructuring" of business activity. There have been many other important effects of computers, but, particularly for personal uses of PCs, penetration and use levels of equipment have not yet reached the restructuring point for personal work or recreational purposes.

In practice, the spread of digital electronic tools will be evolutionary and gradual, but, by traditional standards, it may also be very fast. By the mid-1990s, the required technologies for a major transformation were either available or rapidly becoming so. Most of the tools already exist, but their effectiveness varies. An important deficiency is that most PCs operate as stand-alone units, without the integration that would provide a system, rather than just a "box of tools." And the cost of PCs and various "peripherals" remains far too high for integrated household systems (of the type described in section **11.1.4**) that could help them (PCs and peripherals) reach near-term market penetration levels with serious national implications. One decade does not seem enough for the major changes needed to enable such market penetration of household systems, although (in common with some of the other items covered in section **10.2**) two may suffice.

11.1.4 An Extreme Test

The tools that support the current information environment range in size from tiny chips to enormous printing machines; in complexity, from simple paper clips and stapling machines to personal computer networks and space satellites; and in user-owners, from primarily individuals to large corporations and governments. Over time, the "Age of Mass Literacy" led to the ubiquitous presence of personal tools (principally paper, pencils, and pens) for creating and recording information in durable form and to an accompanying massive distribution of print products intended to serve all kinds of personal and work-related needs for durable, if often temporary, information. It is a rare household or business office in which both classes of tools (writing tools and print products) are not pervasive and whose occupants do not use them easily and comfortably.

How, in these respects, do the newer tools that are the concern of this study fare? The question is important in relation to the typical pattern of technological displacement described above. There is a sense in which the digital information revolution will not be complete until the new devices have achieved a utility-price combination that leads to a level of pervasiveness equivalent to that of the older information tools. Of special interest is their presence and use in the hands of individuals, given this is where the cultural and social impact over time is potentially the greatest.

The answer is a bit complicated, because the new tools appear in two general varieties—as embedded chips or processors (buried in automobiles for ignition and braking control, in thermostats and refrigerators for climate control, etc.), where they are subject to little or no direct user influence; and as devices like PCs and related types of equipment, where user control normally is a critical ingredient. In the first category, digital tools are doing fabulously well; indeed, if the number of embedded chips used in a typical household doesn't already exceed the number of pens and pencils in use, it's only a matter of time until it will. For user-control tools, however, the picture is quite different, although it, too, is changing rapidly.

An extreme test gives a sense of the situation: a set of requirements can be developed for the digital electronic equipment needed in a household to match the usefulness, convenience and comfort provided by current paper-based arrangements. These requirements essentially amount to an integrated household system (see section **11.1.3**). In describing the requirements, the various digital electronic tools are referred to simply as "devices," with some critical characteristics described later.

To start, consider accessibility; to match current practices in the household use of paper products, the following are needed:

- Enough devices available so every member of the household can simultaneously use one. This would enable (and, to some extent, better) actions equivalent to "sectioning" or "tearing up" the daily newspaper, so each family member may have a share.

- In addition, other devices should be located in many rooms of the household, to provide an equivalent to the flexibility offered by having pencils and paper handy throughout the house for impromptu jotting down of notes.

- More powerful devices, located in office or study areas and intended for a variety of serious personal and business purposes as well as special "Game" type devices in recreation areas.

- Specific devices, with appropriate capabilities, located to provide the equivalent of:
  - note pads on refrigerator doors, and
  - note pads, personal telephone lists, and larger telephone directories next to each telephone.

- Additional personal devices ordinarily carried in pockets or handbags. Most of the household devices already mentioned are usually associated with particular uses or locations (i.e., "reading" devices or devices built into or placed next to telephones, etc.) and may not be suitable for uses that require high portability. Devices of the type mentioned here will be needed if the easy portability of many paper-based products is to be matched.

This list suggests how general-purpose paper-based products can be and how narrow in scope most individual current digital electronic devices are. It would take quite a variety of specialized equipment, some already available but much still in development, to meet these household requirements. Further, the full value of the digital electronics environment cannot be achieved without many other kinds of capabilities, seldom found in current versions of the equipment but needed to help create the desired environment. These include:

- **Readiness**—all equipment must be ready to go without delay, such as for "booting."

- **Connectivity**—to avoid the need for constant reentry (and cross-checking) of data items, all "legitimatized" entries into any of the input components of devices must automatically, at the user's request, be made accessible to all other devices in the system "qualified" to handle such information.

- **Simplicity**—especially of data and instruction input, is a key requirement; both limited speech recognition and an equivalent of the "jotting" capability of paper-based tools will be very desirable, as well as improved versions of traditional inputting tools, like keyboards, mouses, etc.

- **Security and Privacy**—separating "public" from "private" information must be simple, either when entered or afterward, and so should protecting the information from unwanted users. A guest or cleaning person must be able to access public information (such as public telephone numbers) and messages addressed to them on appropriate household devices but not be able to access private data, such as financial records of members of the household.

- **Fail-Safe**-since the data entered into the integrated system can become quite voluminous, they may become extremely difficult to replace and reenter, in the event of loss by system failure. For this reason, strong Fail-Safe features must be incorporated.

- **Quality**—good quality, especially of the screens used on reading devices, will be a must for the kind of intensity of use conceived of here.

In ease of availability and device performance, these requirements describe an effort to match (and in many respects exceed) paper tools in their areas of greatest strength. Further, household activities that require using the tools take place in an information-intensive setting and at a higher level of use than is commonly encountered. In the real world, a goal of complete replacement of paper would be foolish. For a long time, situations and uses will exist for which paper systems will provide better tools than the finest digital electro-optic devices available, so coexistence will be the rule.

Pervasiveness, however, is important—not just as a symbol of success, but because it establishes a base of availability that enables users to access and use information better and provides great scope for personalizing uses of information and expressing individuality. None of this can be achieved when the information tools are scarce commodities or narrow-scope, specialized instruments. Pervasiveness ordinarily implies high market penetration, and this, too, has implications.

11.1.5 Limits on Actions

What can be done to mitigate, if not eliminate, the concerns in this and previous chapters and move forward in exploiting the many potential benefits? Before considering potential actions, it is well worth trying to identify explicitly the kinds of steps that cannot or should not be taken. The point has been made several times here that one major result of the forces at work is a continuing process, characterized by an unprecedented pace of change and a (related) unusually high level of uncertainty about the directions these changes will take in the future. All these factors restrict the types of planning that are appropriate.

Traditional business planning techniques were developed to serve organizations that had enough "inertia" in their operations, and among their customers and customer demands, to allow extensive use of forecasts of future demand, production processes, product technologies and the like. For the volatile environment of digital-electro-optics, this approach may be dangerous. Few of the early leaders in computer hardware and software production still survive—and of those that do, fewer still continue in positions of leadership. Many of the failures of early companies resulted from normal competition, but others issued more from an inability to anticipate or cope with changes in the directions taken by the evolving computer activities.

This pattern of a high casualty rate is not in itself unusual in young high-technology industries; much the same kind of shake-out occurred in railroads in the nineteenth century and in the automobile industry early in the twentieth. The pattern does, however, force a different approach on planning. It favors a focus on continuing actions and rapid response to observable processes of change under way, rather than on means to reach any particular desired or anticipated end-position other than the very long and very short—that is, long-term "vision-oriented" goals for broad guidance and relatively short-term targets for ensuring progress.

Focussing on the process under way need not preclude the use of forecasts. Indeed, the focus gains much of its importance from their past high reliability in one key area of technology: the rapid, very steady rate of improvement in performance and the equally steady reductions in costs of solid-state memory and processing chips.[6] In spite of concerns about the continuation of this trend into the future, most observers agree that the change processes have several decades of strength ahead of them. In general, however, forecasting must be used with caution and short-term trends, in particular, must be viewed with suspicion. Optimism about new areas for the use of computers has too often been driven by fads and hype, leading to a rapid cycle of high expectations, numerous new start-up companies, competition to make high-priced acquisitions and, eventually, collapse, failures, and a fading of high hopes to a more reasonable level.[7]

When seeking actions to help cope with the consequences of a fast-paced but uncertain process likely to continue for considerable time, flexibility is important. This need suggests thinking in terms of a series of incremental steps, to be implemented only if or when conditions are favorable to producing near-term results, which are all compatible with a long-term vision or framework. This approach is not traditional, because it involves preparing conceptually for actions that will not be taken until an uncertain future date (if ever) and using a planning framework that should keep evolving throughout the period of implementation. Yet it is not so far from what has often been done by organizations, even if not openly stated. In any case, the situation now faced is not a traditional one.

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[6] Many indications suggest that this high rate may slow in the fairly near future, but a minimum rate at least can be estimated with considerable confidence.

[7] For examples of this process and its impact, see Anthony G. Oettinger, *Telling Ripe from Hype in Multimedia: The Ecstacy and the Agony* (Cambridge, Mass.: Harvard University Program on Information Policy Resources, July 1994, I-94-2).

The remaining pages examine some of the more critical features of the strategic, or framework portion, of the problem. Then, the last few pages are devoted to a review of some features of incremental, step planning, to illustrate both the kinds of accomplishments to be sought and the difficulties that may be encountered in planning and implementing steps of any significant duration.

11.2 A Strategic Framework

The collection of problems faced in the mid-1990s results from a continuous stream of widely interacting changes in the information tools available and in use that have created a very volatile information environment. An appropriate response to them is to focus a planning strategy on procedures that recognize these rather special conditions and are designed to cope with them. Instead of treating forecasts as providing the primary basis for periodic, detailed plans of action, the emphasis must fall on the use of incremental, almost continuous planning methods and on building capabilities to recognize and respond quickly to events. Among other important skills, this approach implies ability to implement projects rapidly.

The following discussion is concerned with some of the features of this approach to planning. Because of its importance to the subject of this report, the area of education is used as a very general example to illustrate features of the planning process.

11.2.1 Attitudes

Strategy must be based on a view of the future, even if that view incorporates a belief in such uncertainty that it restricts the kinds planning that can be useful. A major element in coping well with the evolving information environment will be a deep, almost gut-level acceptance of the expectation of rapid, continuing change with great uncertainty about its direction and pattern. Evidence that this view is appropriate is strong, on the basis of what has happened in the past and on the durability of the trend in technological advances that enabled, and continue to enable, these changes. Acceptance of this view can best be demonstrated by a serious consideration of the enduring consequences that flow from these changes and the adoption of suitable adjustments in response.

Among the most important consequences are those that affect the continuing validity and usefulness of traditional and (usually) strongly held social attitudes. The most relevant of these to this paper are attitudes toward education and literacy. Given the changes ahead, the whole view of education should be open to question. Ideally, the subjects of this review would cover such broad subtopics as the following:

- What are the roles and goals of education in society, in the economy, and in personal life? What were the recognized needs that the education system was established to meet? What significant and relevant areas, if any, were explicitly and deliberately omitted? What areas, if any, simply were overlooked? What new needs have emerged in recent years?

- How adequate and appropriate are the existing formal and informal education systems to meeting current goals and needs? Where are the strengths and weaknesses? How well can the systems adapt to a pattern of continuing rapid change?

- What mechanisms are available for continuing lifelong education? How effective and responsive are they?

- How are effective responsibilities for different areas of education distributed among the main institutions involved—home, school, church, employer, community etc.? What are the responsibilities of the individuals being educated, at different stages of life? Are the responsibilities realistic? Too great, or too few?

- What are the procedures used to determine the views, goals, plans, and other aspects of the public education system? How well established are they, and how responsive to changing needs?

Three points here must be emphasized. First, there is no single set of exact or "correct" answers to these questions.[8] Second, the objective is not to specify correct attitudes but to identify what the attitudes actually are; opportunities to change them will exist and can be important, but not at this step in the process. Finally, what is sought here is a strong sense of awareness about the topics, rather than massive, action-oriented reviews (although these may be important for other purposes). Every nation and every community already have attitudes toward all these subjects, including the passive attitude of neglect toward some. Many of these attitudes will seldom be expressed openly; or if they are, it will be in the form of strong public statements but few, if any, efforts to provide the resources needed to back up statements with action.

A review of the subjects, however, is critical for effective planning. Without that, there are real dangers either of being trapped in old attitudinal responses, without any awareness of their existence, or of proposing changes incompatible with the old attitudes before having prepared the groundwork for dealing with them. In either case, the results could lead to inconsistencies and confusion in implementing plans eventually adopted.

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[8] The examination certainly will need to deal with values that some believe are eternal. Without challenging the values themselves, very significant changes can be made in how they can and should be expressed in the educational system.

11.2.2 General Needs of Today's Education System

Consensus on the general needs facing an educational system is ordinarily achieved by balancing idealized requirements, determined by technological, social, and economic factors, with related obligations, cost limits, priorities, and restrictions, either inherent in or explicitly incorporated into the attitudes just discussed. The requirements usually present possible effective responses to general forces at work on the society, while the related obligations establish the kinds of positions the society can afford and is prepared to adopt.

For the current situation, the basic strategic requirements involve providing individuals with opportunities for continuing lifelong education with:

- curricula that continue to incorporate new (and changing) bodies of knowledge of many different types, some not yet recognized as existing;

- curricula from which older substantive materials are selectively (and continually) eliminated, because of requirements to increase the efficient and effective use of available student time;

- teaching methods that continue to add new (and changing) techniques, with some (or even many) additions accompanied by elimination of methods in which most teachers were originally trained;

- programs that, in total, are appropriate for these conditions but that also offer a variety of possible arrangements, available to both individuals and institutions, regarding time and money costs and related expected outcomes; and

- quality levels appropriate to the goals of each education segment, backed by continuing teacher-training in new materials and techniques and by adequate information and information-tool resources.

The generality of this list is deliberate and is based on two difficulties: the effects of rapid change, which quickly render obsolete many specific requirements (such as for a particular curriculum element) and the complexity of the U.S. education system, which leads to a need for a variety of types of planning. The U.S. system for providing education and training is a mix of public and private (secular and religious) schools and programs within organizations in business and government. The system offers great variety in teaching formats (in person on-site; remote learning using TV, radio, and computer network communications; paper-product correspondence-based courses; computer program-based courses; seminar series; and many others). There is also great variety in the objectives of different participants and a wide spread in the quality of education offered by different providers. The system is in part very responsive to the (near-term) job market and in part blind to all except what (supposedly) worked in the past.

The strength of the system lies in its diversity—as do its weaknesses. Diversity implies that top-down planning, starting at the national level, will be ineffective (and unacceptable) in the United States, in contrast to many nations that have much more centralized and monolithic systems. It also means that each segment of U.S. education providers (and their suppliers, as well) in each distinct student market will face a different situation, so that each will need different detailed planning tactics. All, however, will share the need for a strategy based on anticipating continuing change and uncertainty.

Two strategic needs for operating in this environment have already been pointed out: the need for flexibility and responsiveness and the need for incremental planning within a general strategic framework. Two other needs have equal importance. The first is the need to incorporate into the strategic framework the concept that the problem must be made part of the solution. The family of electro-optic digital computer-related equipment responsible, directly or indirectly, for many problems and concerns now must become a major tool in the measures taken to solve and alleviate them.

The obvious function of computers in this role is to assist in the education process at all levels. Here, as is characteristic of computer applications in many areas, there have been lots of promises, much hype, and a rather mixed delivery. Anecdotal accounts abound of "successes" by individuals and groups using computers for some aspect of learning, but in many cases it seems probable that the students might have done well using any reasonable teaching method. Nevertheless, enough progress has been made to suggest that the time is becoming ripe for wider use of computers in education.

At a more detailed level, judgement of the ripeness of different applications will be a key to successful planning. PC Advisor programs (see section **9.2**) offer examples of a type of application that might eventually be useful in the higher grades of school, where students can handle fairly complete sets of complex instructions. Advisor programs are not yet ripe for wide use; they are just beginning to emerge through such activities as the steady improvement of application "Help" screens.

For the elementary grades of schools, there already are many applications of educational value that offer excitement, stimulus, and rapid "rewards" for young children. For the middle education levels, PCs obviously can be used as routine production and communications tools, as training devices for developing a variety of skills, and as testing devices for many classroom purposes.

Regardless of the particular experiences offered, a key goal for the long term must be integration of PCs into the total school experience, to be employed wherever they might have significant potential use. Treating PCs as special devices, or as a form of "laboratory equipment," simply won't get the job done. If computers can be fully integrated into school activities, evidence suggests that most members of the next generation will adapt to them just as previous generations adapted to earlier technologies—with ease and enthusiasm. Further, by gaining experience at an earlier and better age for learning, the students will develop skills that will be deeper, more intuitive, and better integrated.

The final strategic need is to reemphasize an old and well-recognized purpose of education—one of special importance during times of change. In such times, a high-priority goal of all education, especially primary education, must be to instill in students a capacity—and a strong belief that they have it—to learn new subjects. The ability to keep on learning is the only effective defense against change, and literacy is an extremely important component of the needed learning capability. Further, computers are well on their way to becoming both the most important working tool of literacy and an extremely useful vehicle for instructing students. This combination of functions implies an increasing importance in having all students, at a relatively young age, become "comfortable" working and playing with simple computers, as part of the process of building confidence in their own learning capacity. The need to use computers intensively in the education process is thereby reinforced.

11.3 Incremental Goals and Planning

The discussion of the strategic framework (section **11.2**) covered only process subjects, but obviously other elements are needed, such as a long-range "vision," which can provide guidance (although not too rigorously!) for more detailed incremental action planning. The general strategy itself comes to life only when it leads to effective action plans. Planning for the U. S. education system is, as mentioned, highly decentralized, with plans created and implemented by many types of providers for many market segments. Any attempt to provide even the simplest illustrative examples of such plans at any meaningful level of detail is far beyond the scope of this report. What can be done here, however, is to describe the goal structure for a possible incremental step with some general criteria of success that might be associated with it. This following example illustrates why incremental planning is needed and why efforts devoted to long-range master plans are too often wasted.

This report links technology, literacy, and education, and strongly suggests that future literacy at all levels will require skills in the use of computers by all segments of the population. An appropriate goal to consider, therefore, will seek to incorporate strong elements of PC usage into the literacy-education system. At its most general level, this goal is to establish a broad base of "modern" literacy, which requires all children, starting at a young age, to be able to have useful and rewarding experiences with computers and, in the process, to become prepared for steadily increasing computer experience as they advance in education.

For the public school system in the late 1990s, a high-level statement of this general goal could include the following:

- It would aim to provide means for all school participants to achieve during schooling a level of basic literacy, including appropriate computer skills, so that they could perform the following:
  - They could find, interpret, and understand, without needing significant assistance from others, information commonly distributed through and accessed from computer devices and that is needed to participate effectively in many routine day-to-day life activities.
  - They would have sufficient computer device skills to be able to participate in common computer-based communications activities and have experience in a range of PC work-related activities, which, when extended through the full public school program, will provide (1) a base of acceptable computer skills for admission to higher learning institutions or (2) a variety sufficient to offer the students reasonable assurance of being employable, in most circumstances, with only limited specialized or on-the-job training required.
  - Similarly, they would have skills adequate to facilitate further self-education, either in pursuit of individual interests or to help meet national requirements of some type (such as in the military services).
- It would aim to maintain means to offer education to higher levels of literacy, to those seeking it, where such capabilities may involve the following:
  - increased student awareness of sources of potentially relevant information and the ability to access and employ these sources, which imply skill in the use of available, relatively sophisticated computer-based support tools to locate and retrieve materials (including, for example, use of advanced "Search Agents," if or when suitable versions of them are available);
  - at least some skills in controlling and prioritizing in-bound flows of information materials, to the extent that "Sentry Agents" or equivalent means become available;
  - ability to participate in activities involving computer networks, e-mail, Bulletin Boards and work groups, and other forms of individual and group computer communications;
  - effective skills in using interpretive aids, such as complex and multidimensional graphs and diagrams, dynamic displays, linking mechanisms such as Hypertext and others;

- at least some knowledge and skills in the application of analytical techniques, including use of available "Advisors" to obtain the relevant technical context for employing candidate techniques; and
- an awareness and some knowledge of the more critical global languages or "linguae francae" and of special abbreviations and icons employed in communications and networking operations in different areas of work and for personal interests.

A goal of this type could serve almost immediately as a long-term "vision," intended to provide overall guidance for a long-range program. Some might argue that it already does, but more implicitly, rather than explicitly. In general, however, formal plans (as opposed to goals) should not be adopted until a feasibility check establishes that suitable resources will be available (financial, managerial, technical, materials for starting curricula and training teachers, etc.). Attitudinal problems may be grave at this stage, primarily regarding replacement policy. School Boards are not accustomed to making capital investments for all individual students to have expensive pieces of equipment assigned to them, much less equipment that quickly becomes obsolete and must be replaced every three to five years! Yet this is a real requirement: it may even be the cheapest way to operate, given the costs of maintaining aging PCs. And aging PCs are apt to collect dust faster than most school equipment.

Moving from goals to specific action plans, there are, again, important differences from traditional experience. The incremental approach was suggested because of the pace of change. The fast pace requires that action plans to be designed to be implemented (in at least skeletal form) in three to four years, or less. If it takes longer than this, too many detailed elements of the plan are liable to be at least partly obsolete by the time it is implemented. If this situation appears likely, the goal and action plans need to be segmented into a series of shorter, less ambitious ones.

To become meaningful, the goal should be related to specific output criteria—that is, descriptions of computer skills (using the definition given in **Chapter One** of what constitutes a computer) students will be expected to meet if the plan is successful. Ideally, criteria for success that cover all aspects of a plan should be established as a key element of it. As time passes and the use of PCs spreads and grows more varied, as well as simpler in some ways and more complicated in others, the skill descriptions will need to be reinterpreted, to incorporate changes in PC status (and related adjustments in educational curricula).

Table 5 provides an illustration of the computer-related skills needed to demonstrate *Basic* literacy, in a full sense, in the mid- to late 1990s. It applies to a young person, in that it is oriented toward making the PC a working tool for further education. The requirements could be targeted to be met in the upper classes of elementary school; most of the skills listed already are being used (as of the late 1990s) by at least some pupils at the Third Grade level.[9]

Table 5

Learning about PCs: Opportunities Everyone Should Have (in the mid-1990s)

- To understand and practice or be drilled in safety measures appropriate to working with the particular equipment
- To be at home and comfortable with a PC, i.e., not afraid ot it
- To be able to connect equipment in a simple configuration, handle basic controls, install simple programs, load personal files
- To be skilled at using and controlling both input tools (keyboard, mouse, joystick, stylus, etc.) and output display and able to conduct simple print operations
- To be broadly acquainted with PC capabilities and:
  - Skilled at using simple versions of widely used school and home applications (including school-related communications programs and games)
  - Able to "personalize" these programs and create simple macros to ease personal use of the programs
  - Able to communicate within a network of school PCs (e.g., by E-Mail) and work on PCs singly or as a member of a group
- To be able to organize information in a system, to file information, to search for and retrieve information (manually and from both PC internal memory and a remote in-school source)
- To have an adequate understanding of the terminology used to describe software program capabilities and requirements in order to be able to evaluate intelligently student-level software packages for potential purchase
- To have a feeling for:
  - Common mistakes and the ways things can go wrong
  - Ways to avoid these mistakes, e.g., making backups, etc.
  - Sources of help on screen and in a manual, including an understanding of simple error messages and diagnostics
- To understand the general pattern of information flows among the equipment components in a typical, simple configuration

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[9] It is difficult to build an equivalent table for more advanced literacy skills, which are a function of anticipated fields of application and vary from one field to another. Periodic development of such tables by different professional societies and business organizations could help individuals build their own plans for education (and reeducation).

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The example goal and Table illustrate a basis for describing the dramatic effects of a fast pace of change on planning processes. The example covered a goal that started having practical potential in the mid-1990s:

- Had the goal been established five years or so earlier, the details would have been quite different.
  - The concepts of Agents and Advisors were well established then, but their practicality was not yet demonstrated. They were nowhere near "ripe" enough to be incorporated formally into a public school curriculum plan.
  - Similar remarks apply to communications and interpretation skills. Systems like the Internet were seldom mentioned in the general press then, and PCs lacked the power to use many of the display techniques now fairly common.
  - CD-ROMS were not generally available, without which efforts to develop many kinds of reference and educational programs were limited.

In spite of these more limited capabilities, the PC had many applications; a curriculum covering some of these uses could have been valuable, but not with the goal and planned outputs described here.

- A goal that might be established five years from now should almost certainly be equally different:
  - Many computer-supported tools for information search and flow control, and for some types of analysis and interpretation of information, will be greatly improved and simplified.
  - Networking and other communications programs will be greatly simplified; new networks will be built and the costs for using them will probably be lower.
  - New formats will have emerged, and new means for computer-based groupwork, and for better educational uses of Interactive CD-ROMs.
  - Use of PCs may start becoming fully integrated into all aspects of school curricula, reflecting experience gained and greater computer skills of new cohorts of teachers entering the system.

- Somewhat later, it would not be unreasonable to anticipate two even more dramatic sets of changes, resulting from the availability (at consumer price levels) of high-quality flat panel displays (see section **9.3**) and from at least partial integration of home equipment into cohesive systems, both of which will make major changes in the pattern of use of PCs and make them still more valuable tools.

History teaches that "forecasts" of the future will be wrong, in spite of their generality. Something dramatic and unexpected will happen, and some anticipated changes will fade away. What they do show is that, even if a general forecast were reliable, at the detailed level uncertainty remains great. Although a general strategic framework is needed to furnish guidance, incremental-planning appears to offer the only sensible basis for action.

When all is said and done, there is a strong element of faith in accepting, even embracing, active and often costly measures in an environment as filled with dynamic change as that described here. But there are also strong elements of hope. Computers have made major contributions to the scope, quality, and lower costs of many service industries, and there is no reason why, as experience is gained, they should not do the same for education. Perhaps even more significant in the long term, the emerging vision of what it will mean to be literate in the future is simply too powerful and too important to ignore.

Acronyms

AI	artificial intelligence
CD	compact disk
CD-ROM	CD-read only memory
CNN	Cable News Network
CRT	cathode ray tube
E-mail	electronic mail
GUI	graphical user interface
IMM	interactive multimedia
LAN	local area network
NIST	National Institute of Standards and Technology
PC	personal computers
TV	television
3-D	three-dimensional
VR	virtual reality
WAN	wide area network

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ISBN 1-879716-44-5